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WAR DEPARTMENT

TECHNICAL MANUAL

AIRCRAFT SHEET METAL WORK

February 10, 1941

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AIRCRAFT SHEET METAL WORK

Prepared under direction of the
Chief of the Air Corps

		Paragraphs
SECTION I.	Hand tools and machines	1–3
II.	Soldering	4–8
III.	Elements of sheet metal work	9–13
IV.	Properties and uses of aircraft sheet metal	14–20
V.	Aircraft sheet-metal rivets, screws, and miscellaneous fasteners	21–26
VI.	Wires and cables	27–32
VII.	Bumping and forming methods	33–37
VIII.	Repairs	38–43
IX.	Radiator repair	44–53
X.	Fuel and oil tank repair	54–57
XI.	Airplane plumbing	58–63
XII.	Plastic sheet for aircraft	64–68
XIII.	Protective coatings for aircraft	69–73
XIV.	Cadmium plating	74–77

	Page
Index	

SECTION I

HAND TOOLS AND MACHINES

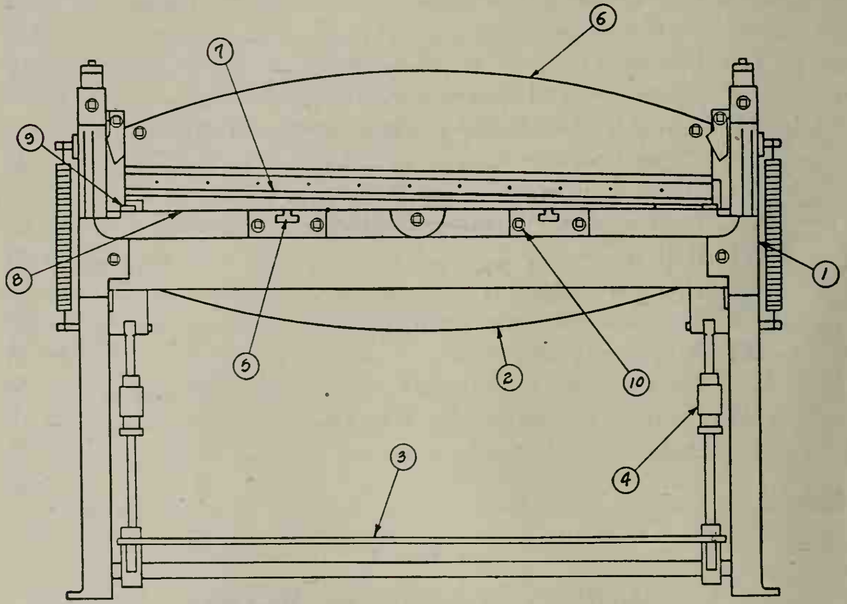
	Paragraph
General	1
Floor and bench tools	2
Hand tools	3

1. **General.**—The sheet metal industry covers an extremely large field, therefore, specialization in one particular phase is essential. This manual contains only information and instructions which are applicable to the aircraft phase of the industry.

2. **Floor and bench tools.**—*a.* The machines and tools described herein are all used in connection with aircraft sheet metal work; however, many of them are also used in other phases of the sheet metal industry.

(1) *Squaring shears* (fig.1).—The squaring shears is a machine used for squaring and cutting sheet metal. The cutting mechanism consists of two blades operated either by foot or motor power. The lower blade is mounted solidly to the bed, which has a scale gradu-

ated in fractions of an inch, for measuring the sheet being cut. The other blade is mounted on the upper cross head and is moved up and down to cut the stock. Foot power squaring shears will generally cut mild carbon steel up to 22 gage. These machines are manufactured in various widths from 12 to 120 inches. To operate the squaring shears, set the long bed gage parallel to or at an angle with the blades according to the shape desired. Place the metal on the bed of the machine and trim off ¼ to ½ inch to make a straight edge on the sheet. Hold the trimmed edge against the gage and shear the sheet to size. To square the sheet, hold the end that has just been cut against the side gage and trim off ¼ to ½ inch. Turn the sheet over, holding the straight edge against the long gage which has been set to the desired distance, and shear the other edge.



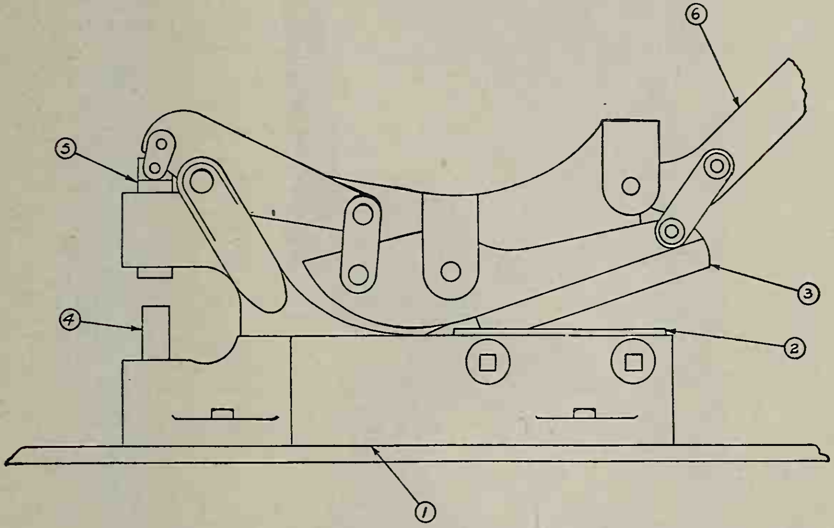
1. Housing and leg.
2. Lower cross head.
3. Foot treadle.
4. Turnbuckle for adjusting blade.
5. T-slot for gage bolt.
6. Upper cross head.
7. Upper blade.
8. Bed.
9. Side gage.
10. Bolt for extension arm.

FIGURE 1.—Squaring shears.

(2) *Gap-squaring shears.*—The gap-squaring shears resemble the regular squaring shears except that the housing is built so that

the sheet may pass completely through the machine, thus permitting the cutting of any length required. The gap-squaring shears are generally used where the regular squaring shears are too narrow to split long sheets.

(3) *Slitting shears* (fig. 2).—The slitting shears are used to slit sheets in lengths where the squaring shears are too narrow to accommodate the piece. Slitting shears of the lever type, for cutting heavier grades of sheet metal, are most commonly used and are known as lever shears. These shears should never be used to cut bolts or rods unless fitted with a special attachment for such work, as narrow, rounded material will break down the cutting edges of the blades. Some lever shears have a punching attachment on the end opposite the blades, for punching heavy sheets.



1. Base.
2. Lower blade.
3. Upper blade.
4. Die.
5. Punch.
6. Handle.

FIGURE 2.—Lever type slitting shears.

(4) *Throatless shears* (fig. 3).—These shears are generally made to cut sheet metal of 10 gage mild carbon, and 12 gage stainless steel. The frame is so constructed that sheets of any length may be cut and the metal may be turned in any direction during the operation, allowing irregular lines to be followed or notches made without distorting the metal.

(5) *Rotary shears* (fig. 4).—Rotary slitting shears consist of a frame with a deep throat fitted with circular disk shaped cutters fastened to

paralleled shafts and connected with gears. The cutting wheels are operated either by a crank or power driven wheel. Shears of this type are used for slitting sheet metal and cutting irregular curves and circles. To operate the rotary shears, hold the edge of the sheet against the gage, press the end of the sheet against the cutting wheel, and turn the handle until the full length of the strip has been cut. For irregular curves, slide the gage back out of the way and turn the handle slowly, keeping the cutting wheels on the line to be cut.

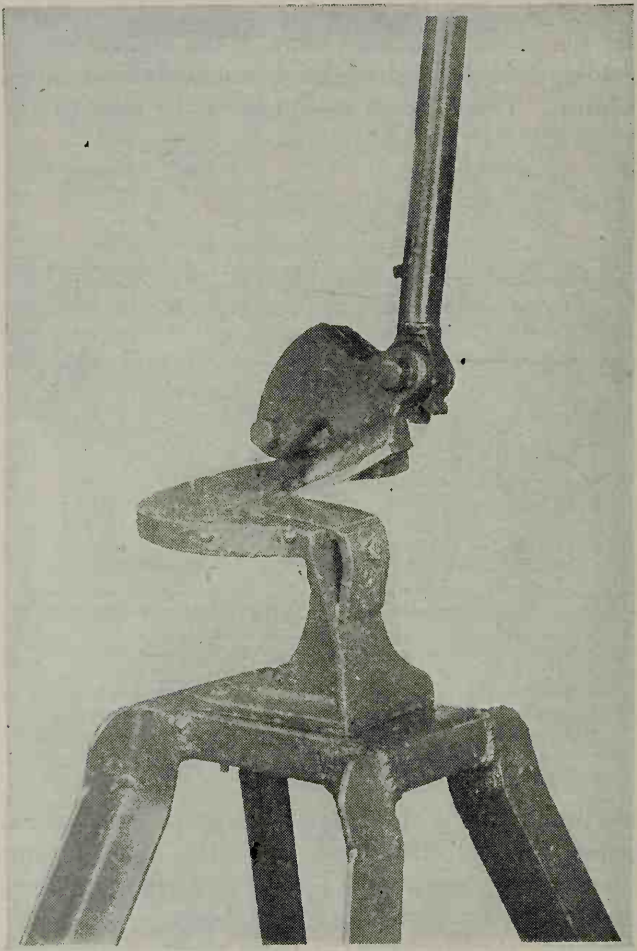
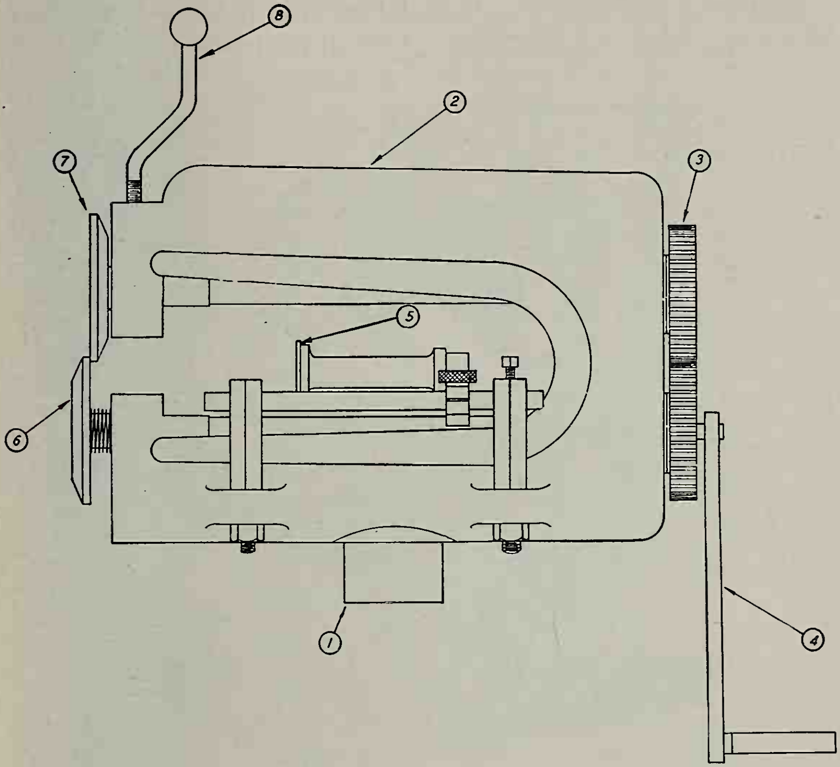


FIGURE 3.—Throatless type lever shears.

(6) *Ring and circular shears.*—The ring and circular shears resemble the rotary shears and are used for cutting true circular disks in

sheet metal. An adjustable sliding attachment is provided for holding material while cutting circles of different diameters. The metal to be sheared should be cut in squares about ¼ inch larger than the circle desired. To operate the ring and circular shears, set the swinging gage so that the distance between the gage and the center of the clamping disks equals one-half the length of one side of the square and set the sliding circle arm so that the distance from the center of the clamping disks to the cutter rolls equals one-half the diameter of the circle desired. Some machines have a graduated scale on the base for setting this sliding arm.



1. Shank for bench standard.	5. Adjustable gage.
2. Frame.	6. Lower rotary cutter.
3. Back gear.	7. Upper rotary cutter.
4. Hand crank.	8. Cutter adjusting screw.

FIGURE 4.—Rotary shears.

(7) *Unishears* (fig. 5).—Unishears is the trade name of the newer type of power circle cutting shears. The size and capacity is desig-

nated by numbers; for example, the number 015 has a capacity for cutting 14 gage cold rolled steel. Adjustments are provided for both horizontal and vertical clearances. Clearance adjustments must be made for all gages of metal with thickness gages furnished with the shears. A machine of this type will cut circles as small as 3 inches in diameter.

(8) *Nibbler* (fig. 6).—The nibbler is similar in design to the unishear. The cutting blade operates with a vertical reciprocating motion and the stroke is longer than that of the unishear. This stroke is adjustable throughout the range of the machine. Nibblers are usually manufactured in sizes to cut mild steel up to ½ inch in thickness and are very useful in manufacturing airplane fittings.

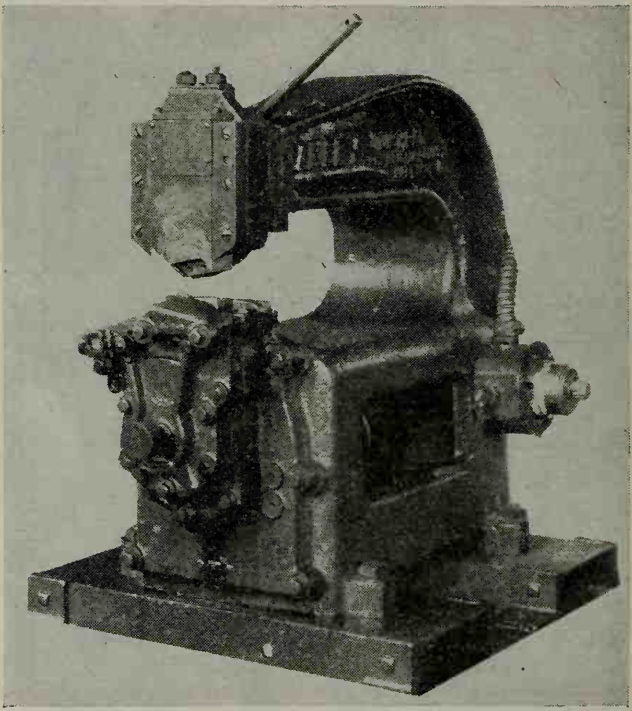


FIGURE 5.—Unishear.

(9) *Folding machines.*—Folding machines are used for such operations as turning edges, flanging, preparing straight sheets for wiring, and preparing the edges of pipes, cans, buckets, boxes, etc., preparatory to grooving. The most commonly used types are the bar folder and the pipe folder.

(*a*) A typical bar folder is shown in figure 7. This machine can be set to turn edges or rounded locks to receive wires. To turn an edge with the bar folder, turn the hand wheel in the rear of the folder to set the gage to the width of the fold desired then tighten the lock screw. The top of the bending leaf should now be even with the top of the folder frame. Hold the metal sheet tightly

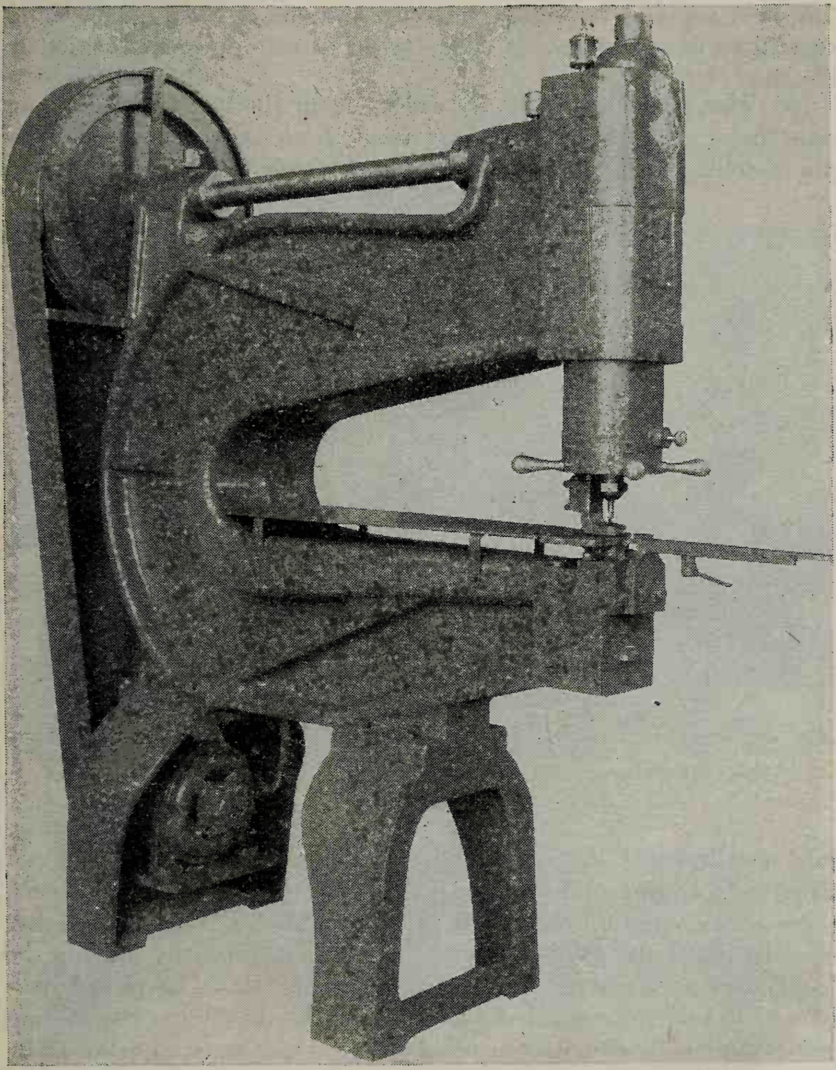
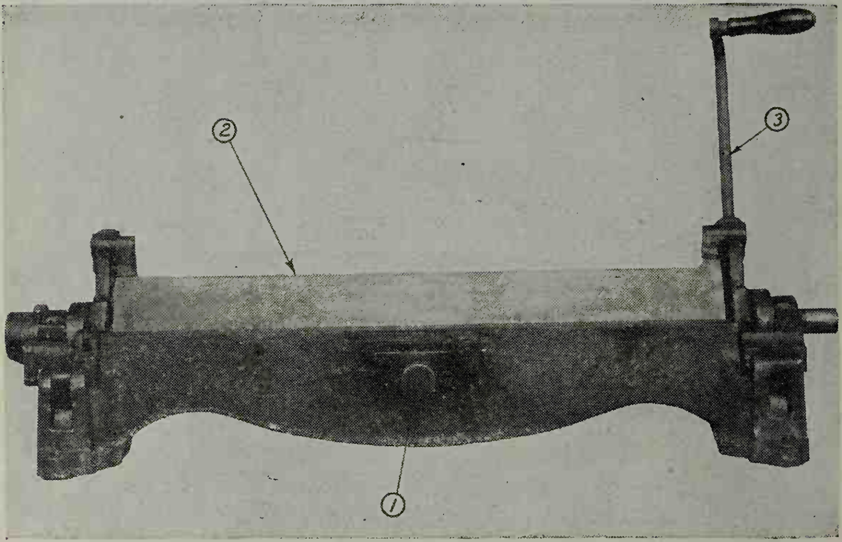


FIGURE 6.—Nibbler.

against the gage and with the handle at the right side of the machine, turn the bending leaf over as far as it will go. Hold the sheet in this position and return the bending leaf to its starting point. Slide the sheet out and repeat the operation on the opposite edge, being careful to have this second edge turned in an opposite direction to the first.

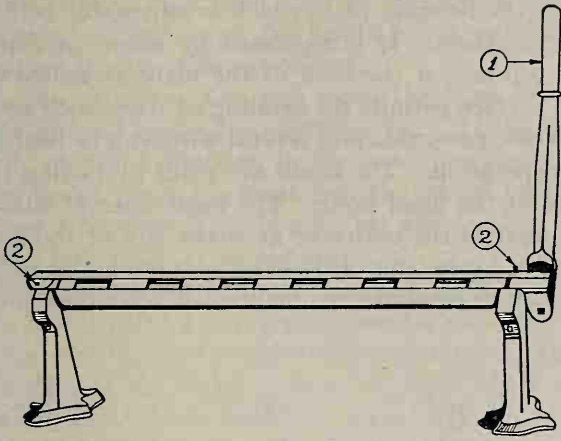
(*b*) The pipe folder (fig. 8) differs from the bar folder both in construction and operation. This device is so constructed that locks can be folded either on the flat sheet or on stock that has been formed into a cylindrical shape (a feature which the bar folder does not have). In edging or forming a lock on a cylinder after it has been shaped, one edge of the metal is inserted between the folder bar and the lip of the folding blade where it is clamped by moving the hand lever to the left. The folding bar may then be pulled over toward the operator until the lock is completed. When the folding bar is pushed back to its original position the work is released by throwing the lever to the right. For forming the opposite edge, the cylinder is inserted as before but over instead of under the folding bar and the operation is repeated. The maximum capacity of this folder is usually 22-gage iron.



1. Wheel for adjusting screw. 2. Bending leaf. 3. Bending leaf handle.

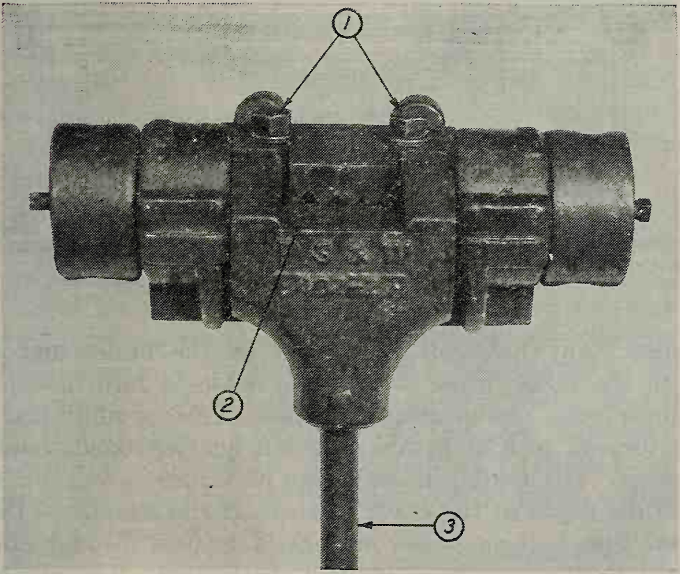
FIGURE 7.—Bar folder.

(10) *Brace and wire bender.*—In the sheet metal shop a great amount of iron bar stock and wire or rod is used for braces, handles,



1. Lever 2. Adjusting screws.

FIGURE 8.—Pipe folder.

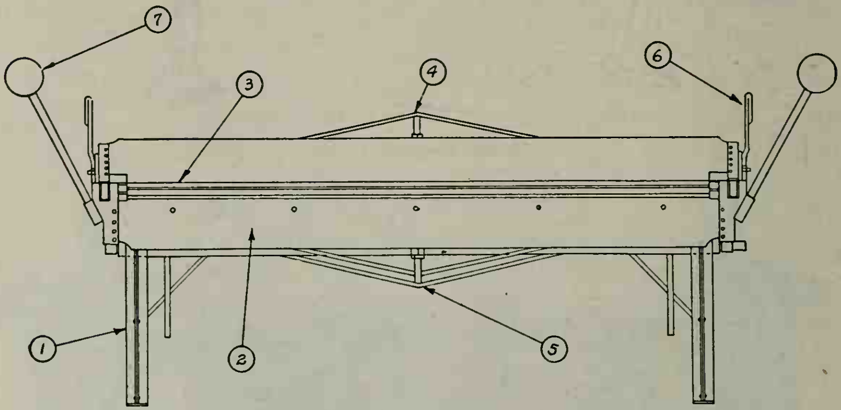


1. Adjusting screws. 2. Wire grooves. 3. Handle.

FIGURE 9.—Brace and wire bender.

etc., on buckets, boxes, and tanks. As this metal is too heavy to form on the folder or cornice brake, it must be bent either in a vise, or brace and wire bender. The brace and wire bender (fig. 9) is much easier and quicker than the vise and leaves the bar or rod in better shape when finished. Flat sheets to be shaped are inserted under the surface of the bending plate which is adjustable both for radius of turn and thickness. It is regulated by means of cap screws located in the top and at the back of the plate as shown in figure 9. The grooved surface permits the bending of wires such as are used in the tops of boxes, pans, etc., and several wires can be bent at the same angle in one operation. The bends are made by raising the bending bar by means of the hand lever. The hand lever is interchangeable and may be used in the center or at either end of the machine.

(11) *Cornice brake* (fig. 10).—The cornice brake differs widely from the folder in construction, manner of operation, and range of usefulness. Any lock can be formed on the brake that can be made on the folder while it is also possible to form double locks, Pittsburgh locks, and countersunk seams. Various additional shapes can be formed, such as square, angular, quarter-round, round, and ogee bends. The folding machine can only form a lock, or edge, as wide as the depth of the jaws; whereas, the brake allows the sheet of metal that is to be edged or formed to pass through the jaws, from the front to the back, without obstruction. The general procedure for using the brake may be outlined as follows:



1. Legs.
2. Bending leaf.
3. Upper clamping bar.
4. Upper truss rod.
5. Lower truss rod.
6. Clamping handle.
7. Balance weight.

FIGURE 10.—Cornice brake.

(*a*) Mark the bend lines on metal to be formed.

(*b*) Open the clamping bar by pushing the handle backward and place the sheet of metal on the table or bed of the brake.

(*c*) Bring the marks, indicating the line of bend, directly under the edge of the clamping bar, then bring the bar down to hold the metal firmly in place.

(*d*) Set the stop at the right side of the brake to indicate the angle or amount of bend, raise the bending leaf until it strikes the stop, then return it to its former position.

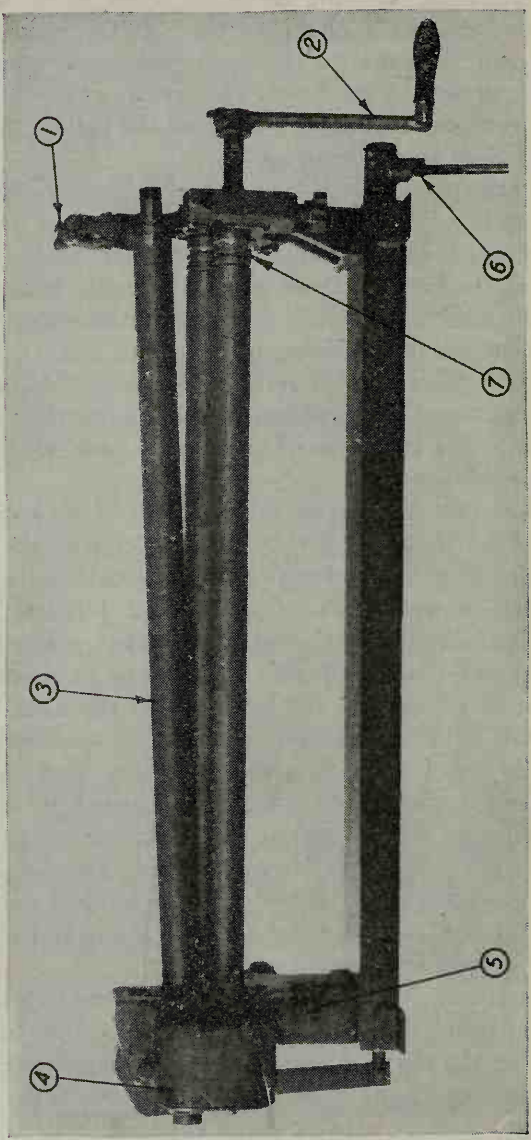
(*e*) Open the clamping bar and move the sheet so as to bring the next line of bend under the clamping bar. If the bend is to be turned in the opposite direction to the bend just made, step to the center of the brake, grasp the sheet near the center, swing it end for end, and place it between the clamping bar and the bed of the brake before placing it in position for bending.

(*f*) To form quarter-round, half-round, or ogee molds, bend the section to be molded to a right angle, clamp a wood mold of desired radius on the bending leaf, open the clamping bar, and place the metal on the bed of the brake. Draw the right angle bend against the wood mold and hold it firmly in place with the clamping bar. With the hands held flat against the back of the metal, carefully bend it over the wood form until it retains the desired shape.

(*g*) When bending metal heavier than 20 gage, move the clamping bar back on the bed—the thickness of the metal—and reinforce the bending leaf with angle iron.

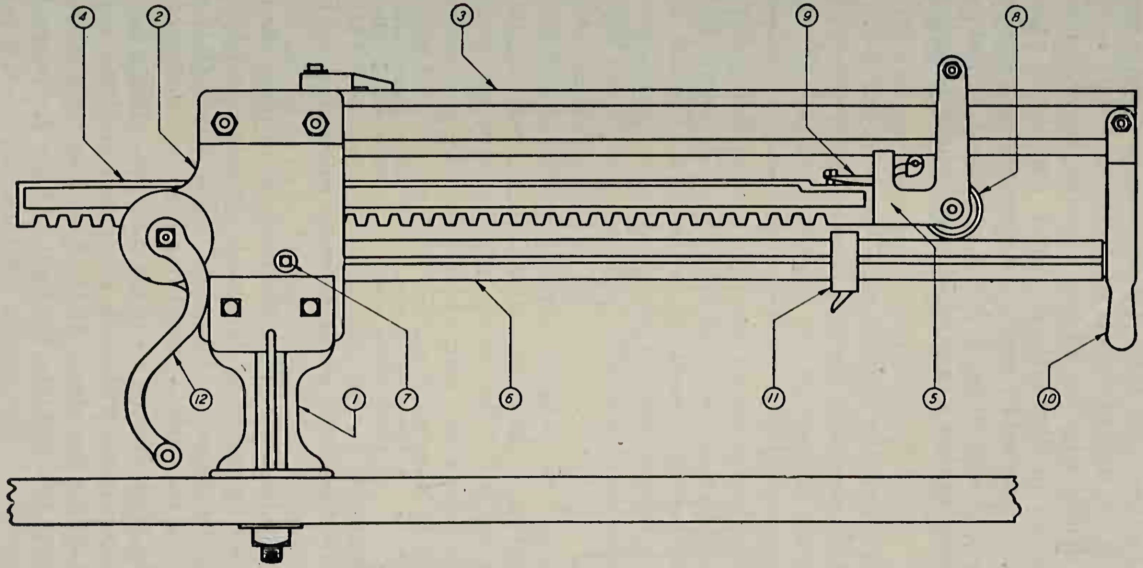
(12) *Forming roll* (fig. 11).—The forming roll is probably used more than any machine in the shop with the exception of the cornice brake. The machine is used for forming sheet metal into cylinders of various diameters and consists of right- and left-end frames, between which are mounted three solid steel rolls, connected with gears, and operated either by means of a hand crank or power drive. The front rolls can be adjusted to the thickness of the metal by two thumb screws located either on the top or bottom of each end frame. These rolls grip the metal when it is started in the machine carrying it to the rear or forming roll which is adjusted in the same manner as the front pair. The forming roll is known as a slip roll former. In this type the top roll is so arranged that one end can be loosened and raised allowing the work to be slipped out at the end preventing distortion of the metal. Small pipes and cylinders can easily be formed on the slip roll former.

(13) *Grooving machine.*—Grooving machines are used following the forming rolls in many operations. The lock or edge is first turned on the rolls then laid on the horn or arm of the grooving machine, and a wheel run over the seam lengthwise making it secure. The grooved wheel is used where the seam is to finish on the outside of the work. Where the seam is to finish on the inside, an adjustable horn or arm with different sizes of grooves is used. The work is placed on the grooving arm in the same position as before and a flat wheel used to



1. Latch.
2. Crank.
3. Gripping roll.
4. Gear box.
5. Adjusting screw.
6. Lifting lever.
7. Wire grooves.

FIGURE 11.—Slip roll former.

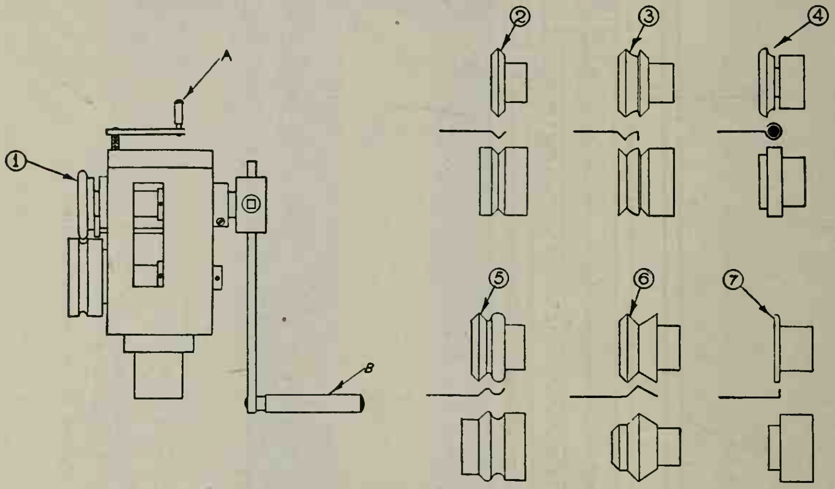


1. Stand.
2. Frame.
3. Upper bar.
4. Rack.
5. Traveling carriage.
6. Grooving horn.
7. Grooving horn adjusting screw.
8. Grooving roll.
9. Tension spring.
10. Latch.
11. Adjustable stop.
12. Hand crank.

FIGURE 12.—Grooving machine.

press the seam down in the groove on the arm. All standard grooving machines have sets of grooving wheels for seams of various widths.

(14) *Turning machine* (fig. 13).—The turning machine is used for preparing a seat in the tops of vessels for receiving a wire as well as for turning the double edge on elbows when no elbow machine is available. As shown in figure 13, an upper and lower wheel are mounted on shafts, connected by gears, and operated by a hand crank. In operation, the cylinder to be wired is permitted to rest on the lower wheel, pressing against a gage which may be adjusted according to the size of wire to be used. With the work set in place the upper roll is turned down by means of the small crank screw (A), until it makes a slight depression in the metal. The crank (B), which controls the rolls, is then turned until one complete revolution has been made, and the small crank (A) is again turned, raising the work slightly. This is continued with each revolution until the required amount is turned up for the wire. As the wheels or rolls are removable most shops have two sets, one for light and one for heavy work.



1. Turning rolls.
2. Wiring rolls.
3. Burring rolls.
4. Elbow edging rolls.
5. Elbow edging rolls.
6. Elbow edging rolls.
7. Elbow edging rolls.

FIGURE 13.—Burring, turning, and wiring machine.

(15) *Wiring machine.*—The wiring machine follows the turning machine in the production of wired edges and its construction is the same as the turning machine with the exception of the rolls. The seat or edge of the metal is notched and turned for receiving the wire by

means of the turning machine, and a wire of the required diameter is placed in this seat. It is then roughly inclosed in the metal with a mallet and the sheet is placed over the lower wheel of the wiring machine against the gage which has been adjusted to the proper distance. The top wheel is set down lightly against the edge of the metal to be wired. After one complete revolution of the crank, the top wheel is set down a little tighter and the operation is repeated until the wire is completely inclosed. The wiring machine is manufactured in sizes for light and heavy work, and like the turning machine, it has interchangeable wheels. Figure 13 shows its construction, and wiring wheels are illustrated at ②.

(16) *Burring machine.*—The burring machine is built on the order of the turning machine with a slight difference in the shape of the wheels. The burring machine can be used in place of the turning machine in some cases but is more difficult to operate. It is used for turning flanges and edges on round covers and in bottoms for cans and tanks. This machine may also be used for double seaming and for turning single edges on elbows. More practice is required to turn a smooth edge, free from buckles, with the burring machine than with the turning machine. The wheels are interchangeable and are shown at ③, figure 13.

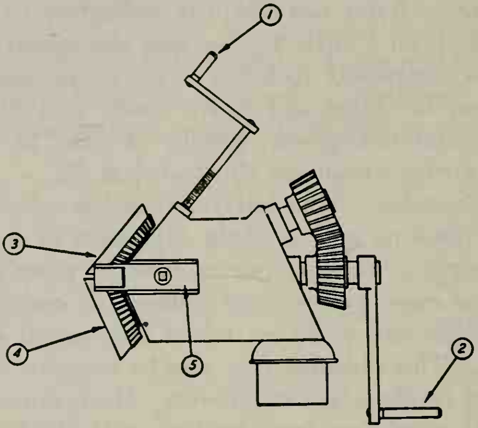
(17) *Elbow machines.*—Elbow machines are the same in construction and operation as the turning or burring machines, with the exception of the edging rolls, which vary in shape according to the type of the edge desired. These rolls will fit any standard make of turning or burring machine and are illustrated at ④, ⑤, ⑥, and ⑦, figure 13.

(18) *Setting-down machine* (fig. 14).—The setting-down machine is used for tightening or setting down the edges made on the burring machine preparatory to double seaming. It is operated on the order of the turning machine. Two styles are available—one with the upper wheel perpendicular and at right angles to the lower wheel, and the other with both wheels inclined toward the machine at the same angle.

(19) *Double-seaming machine.*—After the setting down operation has been performed on the bottom of the object the seam must be turned up tight against the side, either by means of a mallet over a stake or by a double-seaming machine. This makes the vessel stronger as well as producing a tight joint. The edge to be double seamed in the machine is started with a mallet or pliers and finished on the horizontal disk or wheel. The wheel must be of a size to fit snugly on the inside of the work and as the crank is turned the

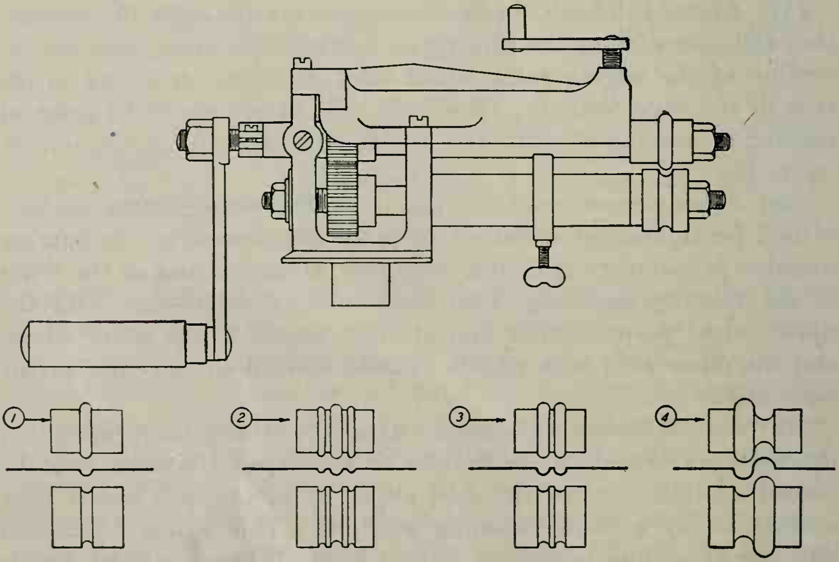
upper wheel must be tightened with each revolution of the material until the seam is tight.

(20) *Beading machines* (fig. 15).—The beading machine is used to turn beads on pipes, cans, buckets, or fenders, both for stiffening



1. Face adjuster.
2. Hand crank.
3. Upper face.
4. Lower face.
5. Gage.

FIGURE 14.—Setting-down machine.



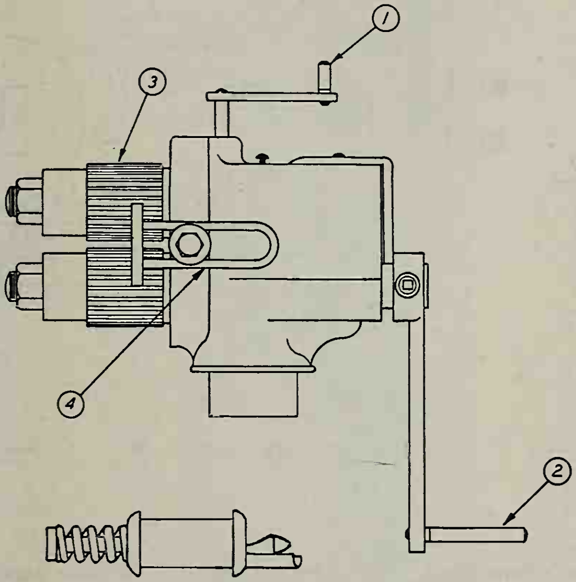
1. Single beading roll.
2. Triple beading roll.
3. Double beading roll.
4. Ogee beading roll.

FIGURE 15.—Beading machine.

and ornamental purposes. It may also be used on sheet stock that is to be welded, to prevent buckling and breaking of the metal.

(21) *Crimping machines* (fig. 16).—The crimping machine is used to make one end of a pipe joint smaller so that several sections may be slipped together. The operating mechanism is similar to that of the beading machine.

(22) *Combination rotary machine* (fig. 17).—This machine is a three-speed, motor-driven combination of the burring, turning, wiring, elbow-edging, beading, crimping, and slitting machines. It is furnished with a spanner wrench for quickly changing the different rolls. The combination rotary machine is especially useful where a number of pieces are to be run through the same operation, as it saves changing the work to the various hand operated units. Figure 17 shows the combination rotary machine with the different types of rolls and the various edges that may be turned with them.

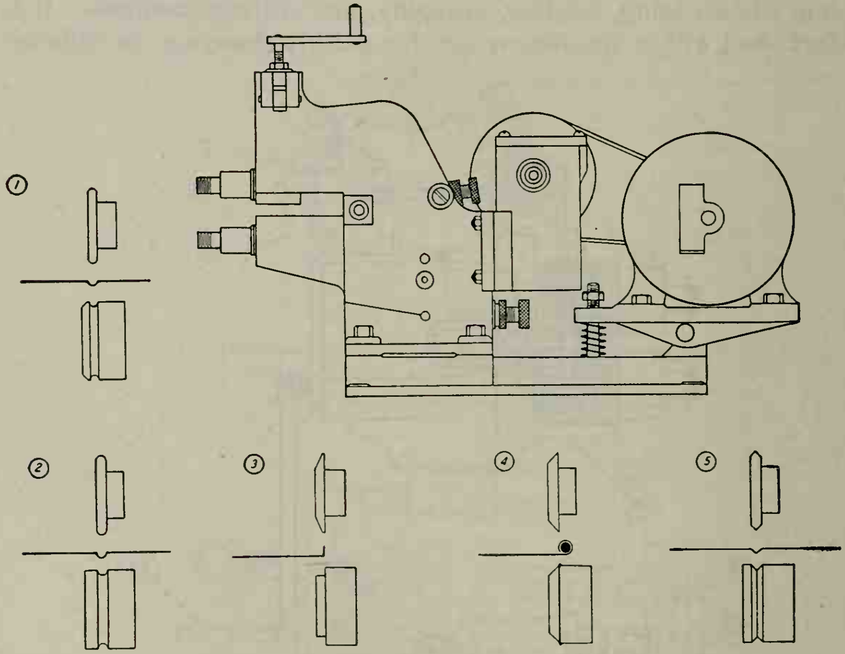


1. Vertical adjustment handle.
2. Crank.
3. Crimping rolls.
4. Adjustable gage.

FIGURE 16.—Crimping machine.

(23) *Power raising hammer* (fig. 18).—The power raising hammer is designed primarily for automobile body work, but owing to its speed in working heavier metals it has been adopted by aircraft manufacturers for such work as raising, flanging, riveting, scarfing, and flattening of sheet metal parts. This hammer is built in two sizes. The small

size bolts to a wooden column extending from the floor to the ceiling while the large size is bolted to a large cast iron column, having a very heavy base, which is a standard part of the hammer equipment. The stroke or force of the blow is controlled entirely by a foot pedal. A movement of this pedal shifts the spindle pin, which governs the stroke, so that the speed is never decreased or effected. The number of blows is approximately 1,200 per minute. The lower die is a vertically adjustable member which can be set quickly to any height to suit different classes of work or types of dies. Many different forms of bumping and shaping dies can be used and are held in place by tight fitting wedges which make quick changes possible. All regular and special shaped dies have hardened and polished faces and there should always be metal between the dies when hammer is being used.



1. Thin turning rolls.
2. Thick turning rolls.
3. Burring rolls.
4. Wiring rolls.
5. Elbow edging rolls.

FIGURE 17.—Combination rotary machine.

(24) *Metal cutting band saw* (fig. 19).—Often in the repair and replacement of airplane fittings, the plate material from which the fittings are made is too heavy to be cut with shears, and the time required to set up such a job on a milling machine or shaper is

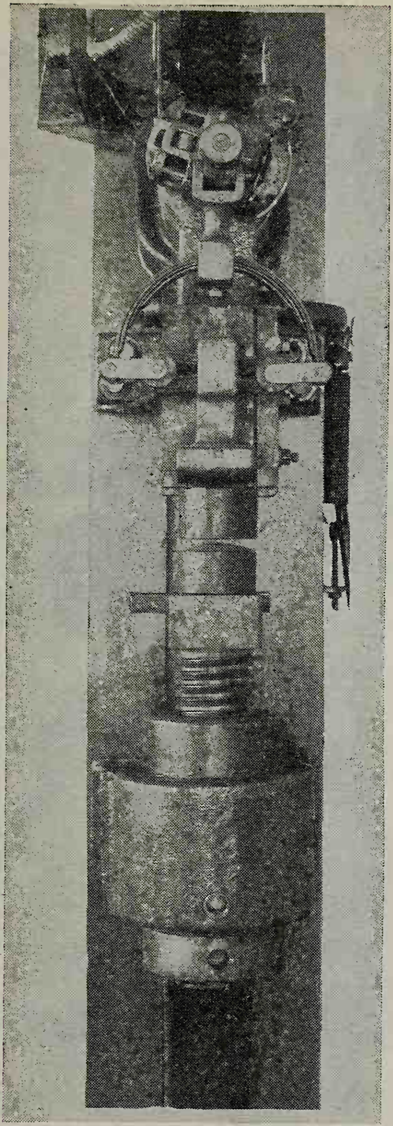
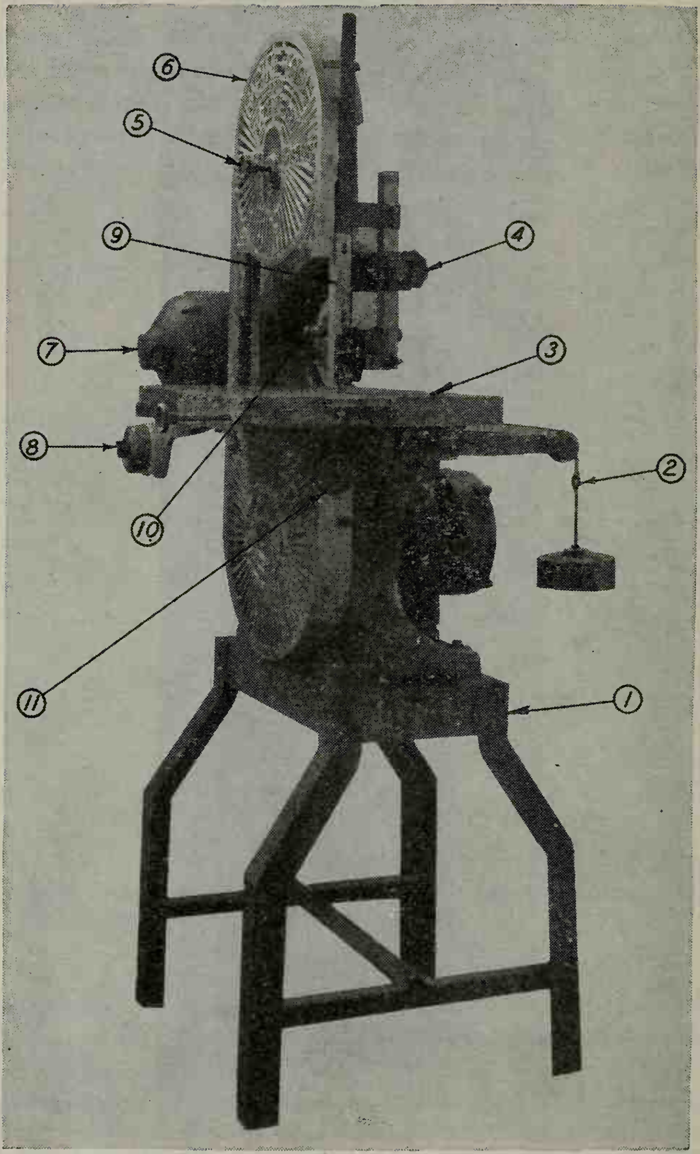


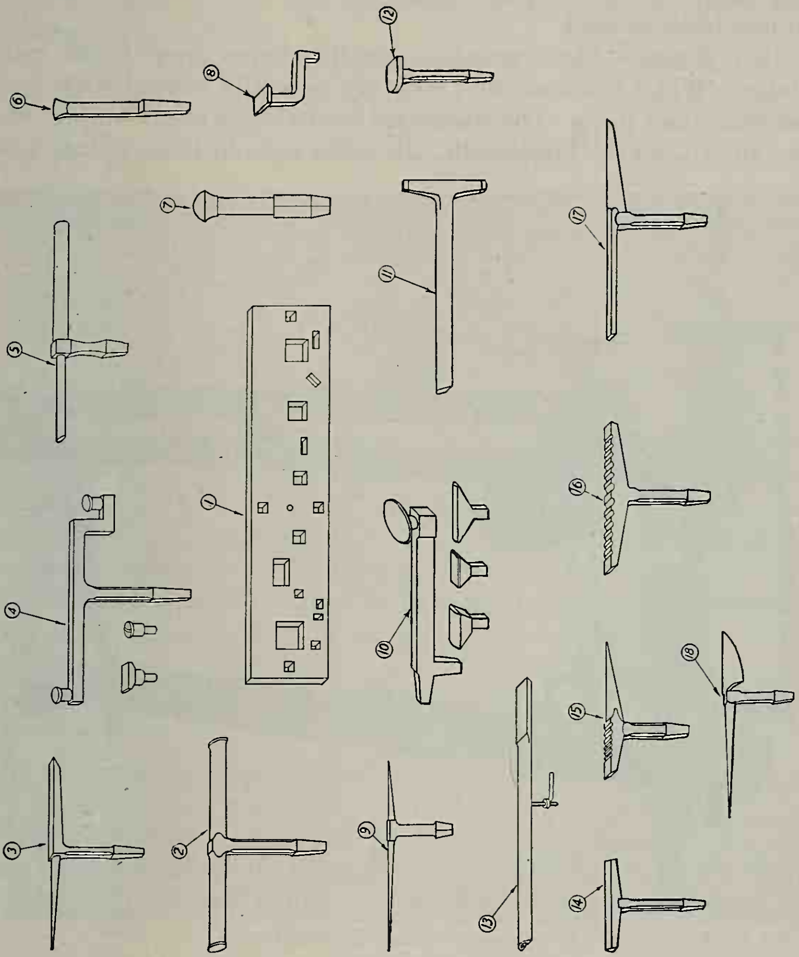
FIGURE 18.—Power hammer.

prohibitive. In such cases the pieces may be blanked out or cut to approximate shape on the metal cutting band saw. This machine has two speeds and is provided with a sliding table having a gravity feed. The work may be secured in a vise attached to the table which has a swivel mounting that allows various angles to be cut, or the



1. Stand.
2. Weight for table.
3. Table.
4. Guide adjusting screw.
5. Speed change knob.
6. Guard.
7. Motor.
8. Switch.
9. Blade guard.
10. Upper guard lock.
11. Lower guard lock.

FIGURE 19.—Metal cutting band saw.



1. Bench plate.
2. Double seaming stake.
3. Needle case stake.
4. Teakettle stake with four steel heads.
5. Conduction stake.
6. Bottom stake.
7. Round head stake.
8. Bevel edge square stake.
9. Candle mold stake.
10. Double seaming stake with heads A, B, C, and D.
11. Solid mandrel stake.
12. Coppersmith's square stake.
13. Hollow mandrel stake with clamps.
14. Hatchet stake.
15. Creasing stake with horn.
16. Creasing stake.
17. Beak horn stake.
18. Blow horn stake.

FIGURE 20.—Bench plate and stakes.

vise may be removed entirely for making straight cuts on large pieces. A great many different materials can be cut on this saw provided the proper blade is used.

(25) *Stakes.*—Sheet metal is usually shaped over forms called stakes. While not machines, they are generally classed with bench machines and tools. The stakes are to the sheet metal worker what the anvil is to the blacksmith. In order to hold these stakes, a flat iron plate, with square tapered holes, is fastened to the bench and the stakes are set in these holes so as to be held securely while work is being performed. Stakes of various shapes and designs, together with the bench plate, are shown in figure 20.

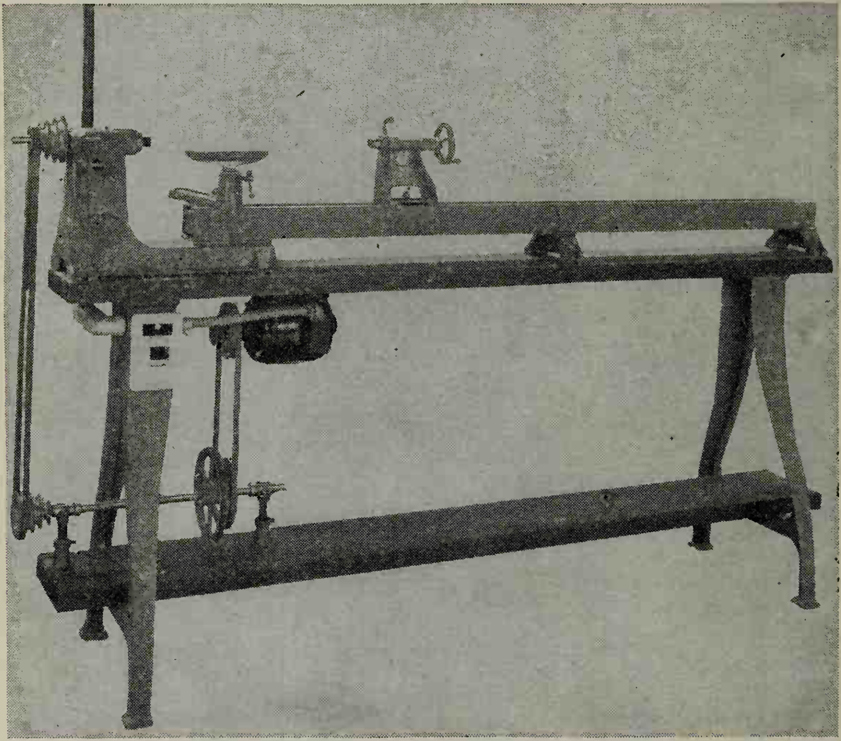


FIGURE 21.—Metal spinning lathe.

(26) *Spinning lathes* (fig. 21).—The spinning lathe is unlike other metal lathes insofar as it has no back gears, carriage, or lead screws. It is very rigid in construction and the spindle is usually driven by means of a step cone pulley.

(*a*) Speed is a very important factor in metal spinning and all lathes made for this purpose are adjustable over a considerable range. Definite speed rules cannot be given as the thicker the metal the slower must be the speed; however, the approximate speeds for spinning are given below:

Metal	Spindle speed (r. p. m)
1/33-inch mild carbon steel	600
1/16-inch mild carbon steel	400
Zinc	1,000 to 1,400
Copper	800 to 1,000
Brass and aluminum	800 to 1,200
Britannia and silver	800 to 1,100

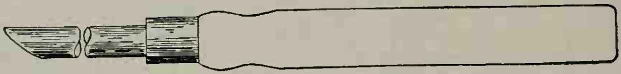
(*b*) Forms or chucks, over which the metal is spun, are made in various shapes, depending on the design of the articles to be produced. Solid forms are generally made of blocks of kiln dried maple. The block is bored and threaded to fit the lathe spindle and turned to the desired form, making allowance for the thickness of the metal. Where a large number of pieces are to be spun over the same chuck, the form is made of lignum-vitae or similar material. Sectional forms are generally made of bronze, with a cast iron or steel bushing.

(*c*) Various shapes of spinning tools are shown in figure 22 and are used as follows:

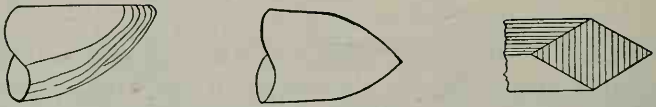
1. *Hand tool holder.*—A grip for holding the various forming tools.
2. *All purpose flat tool.*—One portion of the tip is flat for smoothing purposes, while the opposite side is rounded for breaking down and spinning to chuck purposes. It will perform 65 percent of all spinning operations on soft metals such as pewter or aluminum.
3. *Pointing tool.*—Used for spinning the disk to the chuck and for bearing into curves of small radii.
4. *Cut-off tool.*—Used for trimming excess metal from the lip of the spun object and for rounding off sharp edges.
5. *Beading tool.*—Used for turning the edge of a spun object to a beaded lip. It can also be used for grooving shallow notches. The rolls are of various designs and are interchangeable.
6. *Ball tool.*—Used only on the harder metals such as brass, copper, or steel, and then only for breaking down.

b. Lubricants.—The friction developed while spinning makes a lubricant on the surface of the metal necessary. Cup grease or yellow laundry soap is used for pewter, aluminum, and copper. In using cup grease it may be applied with a dauber made of heavy fabric rolled into a cylinder about 1 inch in diameter. Tallow candles are often used for the extremely hard metals.

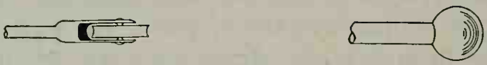
3. **Hand tools.**—A description of the various hand tools used by the aircraft sheet metal worker is given in *a* to *n* below.



① Hand tool holder.



② All purpose flat tool. ③ Pointing tool. ④ Cut-off tool.



⑤ Beading tool. ⑥ Ball tool.

FIGURE 22.—Hand spinning tools.

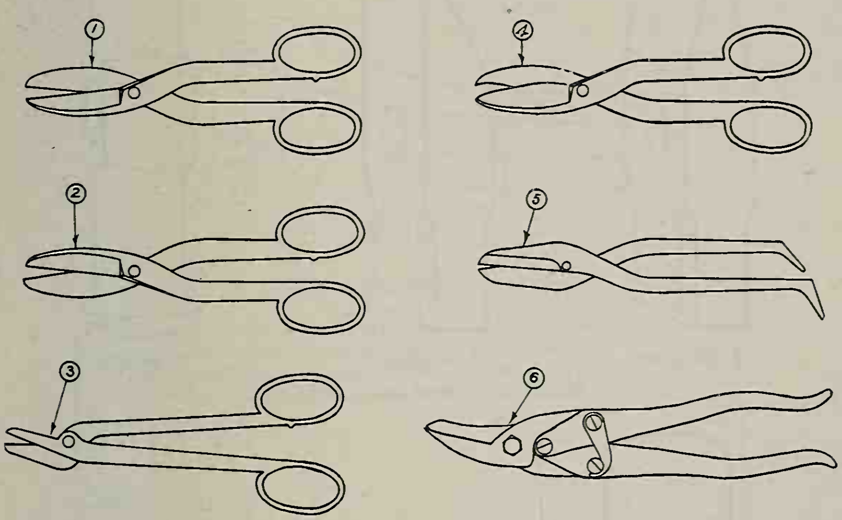
a. Hand snips and shears (fig. 23).—Hand snips are made in various sizes and in the straight, regular, and circular types. First-class hand snips have tapered blades with an inlaid steel cutting edge and sloping shoulders. They are made to fit the hand at the grips or bows and are formed and centered so as to give a maximum leverage for cutting. Hand snips are used to cut metal as heavy as 20 gage.

(1) The regular or straight snips (figs. 23① and ②) are used for cutting a straight line or circle of large diameter. To cut, place the upper blade of the snips on the line to be followed, keeping the blade perpendicular to the surface of the metal, and holding the shears straight up and down. Waste metal, or the smaller piece, should curl up on the upper side of the lower blade. Straight snips may be obtained either for a right- or left-hand operator. Snips should never be used in place of pliers or wire cutters nor should they be used on material heavier than that for which they are intended as snips that have been sprung are useless.

(2) Double cutting shears (fig. 23③) have a top blade with a double cutting edge into which the lower blade works. They are used for cutting light sheet iron pipe, stacks, and cylinders.

(3) Circle snips (fig. 23④) are used for scrolls and circles of small diameters and have curved blades. To cut a circular opening in a sheet of metal, it is necessary to first punch or cut a hole on the inside of the outline of the desired opening so that the blades of the snips may be started.

(4) Bench shears (fig. 23⑤) may be used for cutting sheet metal from 20 to 16 gage. Bench shears are large shears designed so that the lower shank fits in the bench plate allowing the upper shank to be raised and lowered by hand.



1. Right-hand straight snips.
2. Left-hand straight snips.
3. Double cutting shears.
4. Circular cutting shears.
5. Bench shears.
6. Aviation snips.

FIGURE 23.—Tin snips and bench shears.

(5) Aviation snips (fig. 23⑥) are constructed especially for cutting heat-treated aluminum alloy and stainless steel. The blades have small teeth on their cutting edges and the handles are made so as to give greater leverage for heavy cutting. The usual limit of this tool is 0.050 inch stock.

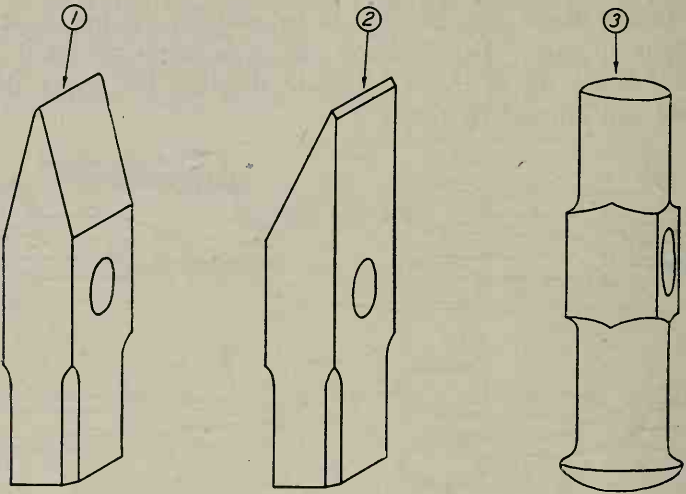
b. Hammers.—Hammers are classed as riveting, setting, raising, etc., and the various types are shown in figure 24.

(1) Riveting hammers (fig. 24①) are used for riveting and light chiseling. They are made in sizes from ⅝ to 1⅛ inches, measured across the face.

(2) Setting (or peening) hammers (fig. 24②) are used to peen or set single seams down tightly on lids, bottoms, etc.

(3) Raising hammers (fig. 24③) are made in a number of sizes and are used to raise soft and semisoft metal to curved shapes.

c. Mallet.—The mallet (fig. 25) is a hammerlike tool made of hickory, rawhide, or rubber, and is used for pounding down seams and forming sheets over stakes. The mallet will not dent or mar the metal like a steel hammer.



1. Riveting. 2. Setting. 3. Raising.

FIGURE 24.—Sheet metal hammers.

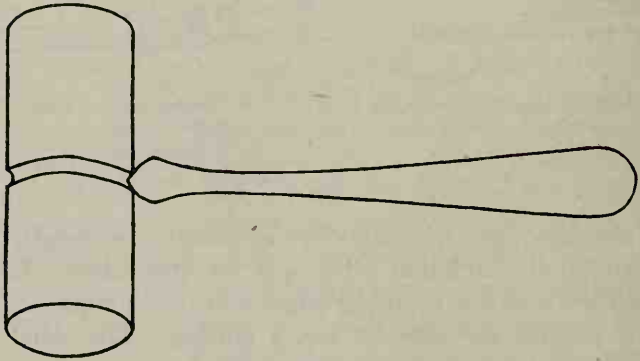
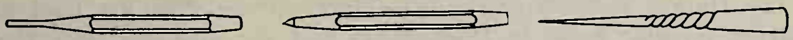


FIGURE 25.—Mallet.

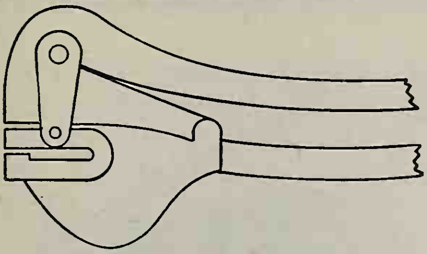
d. Punches.—The various types of solid and hollow punches are shown in figure 26.

(1) Solid punches (fig. 26①) range in size from ⅛ inch to ½ inch. The Whitney lever punch (fig. 26⑤) has largely taken the

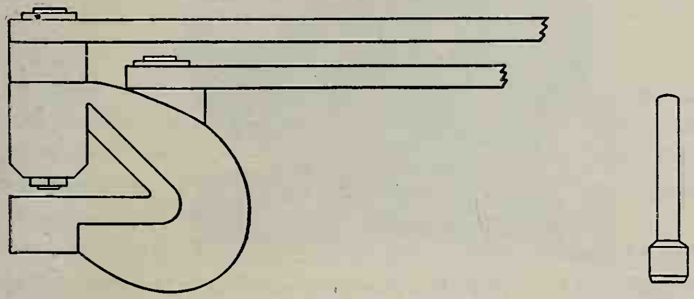
place of the hand type solid punch. The Whitney punch makes a clean sharp hole, free from burs, and will punch heavier sheets with less time and labor. These punches come in a number of styles and capacities. Two of the most popular ones are the No. 5 hand punch of the lever type which will punch ¼-inch hole in 16 gage iron, and the No. 10 ball bearing rotary type which will punch a ⅜-inch hole in ¼-inch hot rolled steel.



① Solid punch. ② Center punch. ③ Prick punch or scratch awl.



④ Whitney punch with lever type handle.



⑤ Whitney punch with rotary type handle. ⑥ Hollow punch.

FIGURE 26.—Sheet metal punches.

(2) When punching holes with the lever punch insert the metal between the die and the punch so that the center punch mark, indicating the location of the hole, is directly under the center of the punch, then pull the handle down slowly until the punch is forced through the metal. Keep the bearings of the punch well oiled and, on heavy metal, put a drop of oil where the hole is to be punched.

(3) The center punch (fig. 26② is used for locating holes to be

drilled as well as for various marking, punching, and locking operations.

(4) The prick punch or scratch awl (fig. 26③) is used for lay-out work on sheet and plate. The scratch awl should not be used on aluminum alloy sheet as the surface of the metal must be kept free from scratches to prevent fatigue failure.

(5) Hollow punches of the type shown in fig. 26⑥ are used for cutting circular holes in sheet metal and are made in sizes from ¼ inch to 3½ inches. In using the hollow punch, the work should be placed on a lead or hard wood block to avoid chipping the cutting edges.

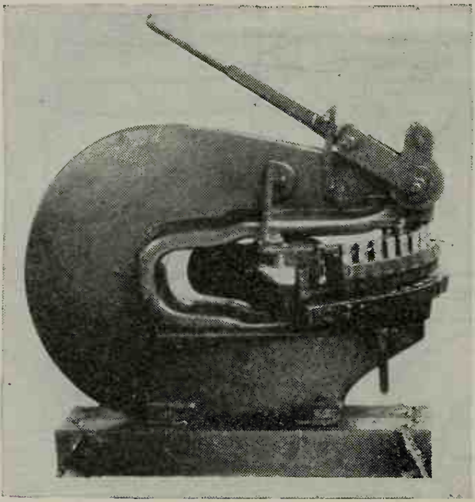


FIGURE 27.—Rotex punch.

(6) Where there is a large amount of work being done necessitating the punching of holes in quantities, such as in baffle plates for fuel tanks, etc., the Rotex quick change type of punch press (fig. 27) may be used to advantage. This type of punch press has a deep throat and a variety of mounted punches and shears any one of which may be put into operation instantly. The shears, punches, and dies, are mounted on a movable tool holder permitting the selected tool to be placed in working position quickly. Standard equipment consists of a selection of nine punches and a 2-inch shear. The punches generally range from $\frac{5}{32}$ inch to 2 inches in diameter and several of the dies are slightly oversize to allow clearance for bolts and rivets. The capacities of the various punches used in the Rotex press are as follows:

Punch diameter	Capacity
Inches	*Sheet metal gage*
5/32 to 1/4	11
3/8 to 1/2	16
3/4 to 1	18
1½ to 2	20

The shears will cut 16 gage metal and cuts may be started at any point on the sheet.

e. Rivet sets (fig. 28).—Rivet sets are used for drawing rivets through sheet metal and for heading them over. They are available in various sizes corresponding to the size of the rivets used. The range is from 1/16 to 5/16 inch, for general work, although special sets, both smaller and larger, may be obtained. To draw rivets through light metal without drilling or punching, place a rivet on a stake, hold the metal in place over the rivet, and strike lightly with a hammer over the stem of the rivet until a raised spot on the metal indicates its exact location. Place a rivet set over the rivet and strike the set with a hammer to draw the rivet through the metal.

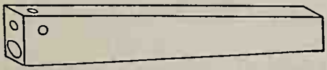


FIGURE 28.—Rivet set.

f. Hand groovers (fig. 29).—The hand groover is used for grooving or creasing seams of material that cannot be grooved on the machine.

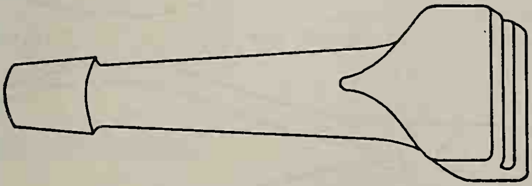


FIGURE 29.—Hand groover.

These groovers range from 3/32 to 19/32 inch in width and may be used on steel as heavy as 22 gage. In grooving seams with the hand groover, hook the folded edges of the seam together and place over a stake. Fit a hand groover over the seam at one end and strike it with a hammer. Repeat this at the other end to keep the edges from coming apart, then continue the operation along the entire length of the seam. The width of the groove should be slightly greater than the width of the seam. Finish the seam by flattening it with a mallet.

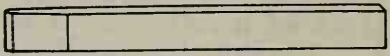


FIGURE 30.—Flat chisel.

g. Chisels.—Chisels used for sheet metal work are either flat or hexagonal. The most common types are from 3/8 to 5/8 of an inch wide. A flat chisel is shown in figure 30.

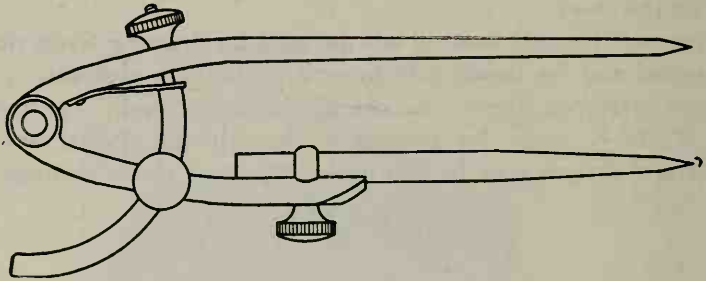
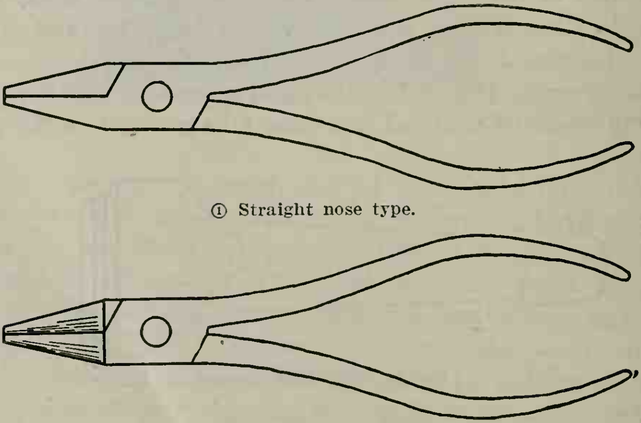


FIGURE 31.—Extension leg dividers.

h. Dividers.—Figure 31 shows a pair of dividers, designed for sheet metal work. These are made of high grade, tempered steel and are known as extension leg dividers. One leg can be lengthened or shortened, as required, or taken out and used as a scratch awl.



① Straight nose type.

② Round nose type.

FIGURE 32.—Metal worker's pliers.

i. Pliers.—Sheet metal pliers are flat-nosed (fig. 32①) for regular operations and round-nosed (fig. 32②) for radiator and bead work. Both types are usually furnished in sizes from 6 to 10 inches.

j. Hand seamers (fig. 33).—These tools are usually classed with pliers and resemble them somewhat. They have a wide blade for making seams and bends by hand where a machine could not be used conveniently.

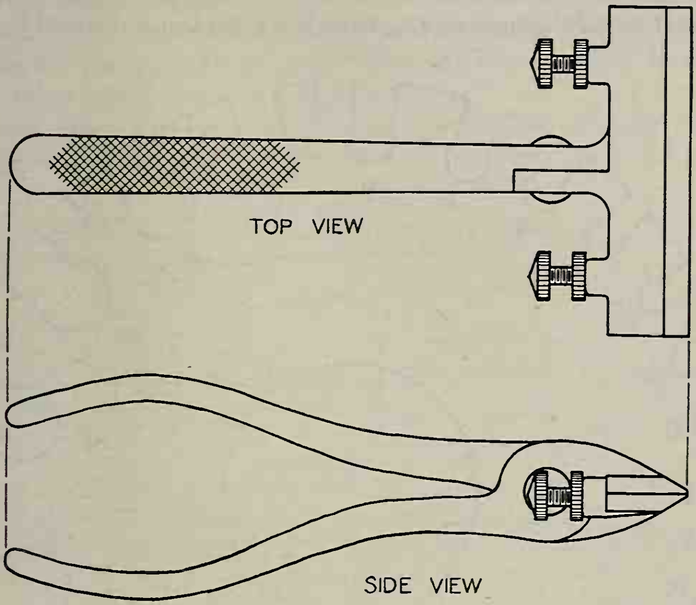


Figure 33.—Hand seamers.

k. Circumference rule.—The circumference rule (fig. 34) is made of high grade steel graduated in eights of an inch. The lower edge shows the exact circumference of a cylinder by referring to the required diameter mark on the upper edge. For example, if the circumference of a cylinder 5 inches in diameter is desired. directly below the 5-inch mark on the regular scale will be found 15¾ inches, which is the required

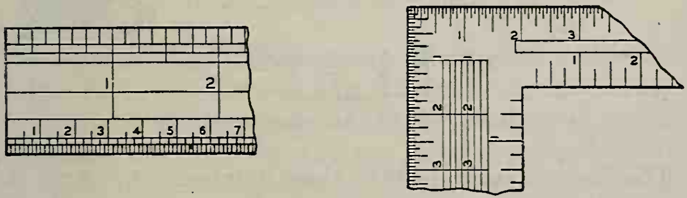


Figure 34.—Circumference rule and steel square.

circumference. On the opposite side of the rule are measurements for straight and flaring pails, flat or pitched tops, and liquid or dry measures. The tool may also be used as a steel square.

l. Wire and sheet metal gage.—(1) This gage is used for measuring the diameter of wire and the thickness of sheet metal. Wire diameters and sheet metal thicknesses are, with few exceptions, denoted by numbers. The decimal equivalents of these numbers are not all the same due to the fact that numerous standards are in general use. The most common of these standards in airplane work are—Brown and Sharp (B&S), National Wire (NW), United States Standard (USS), and Birmingham Wire (BW).

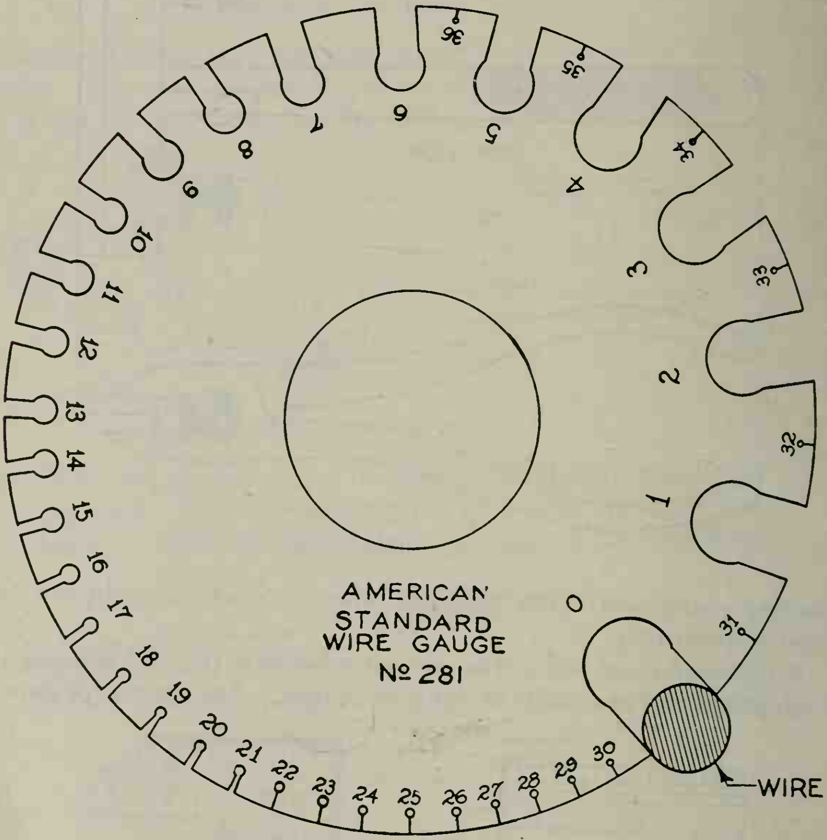

AMERICAN
STANDARD
WIRE GAUGE
Nº 281
WIRE
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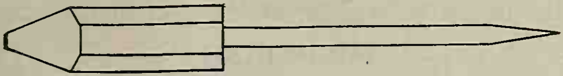
FIGURE 35.—Wire and sheet metal gage.

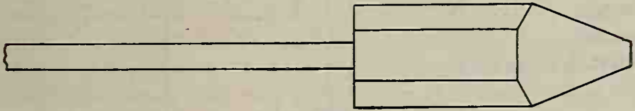
(2) There are several forms of wire gages the most common of which is a circular disk with slots cut in its periphery as shown in figure 35.

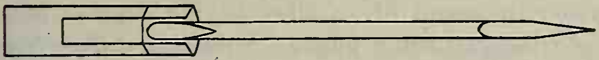
The slots are numbered to indicate dimensions and measurements taken by inserting the sheet metal or wire into the slot. (Comparative gage dimensions may be had by referring to suitable tables.)

m. Soldering coppers (fig. 36).—Soldering coppers are forged from solid bars of copper. They are available in sizes ranging from 1 to 5 pounds and have a short iron shank set in the copper to which is attached a wood handle or grip. They are made in four standard shapes all of which are shown in figure 36.

n. Fire pots.—Fire pots or furnaces are used for heating soldering coppers. They are manufactured in various types and styles depending upon the fuel to be used and the nature of their requirements. The fuels used for fire pots are gasoline, charcoal, and gas. Where gasoline is always available a type of furnace burning this fuel is generally used. To operate the gasoline fire pot, fill the tank about three-fourths full of regular gasoline (do not use ethyl or other prepared fuel) and screw the filler plug securely in place. Give the pump six or eight strokes to supply enough air pressure for starting. Open the needle valve and fill the drip cup. As soon as it is full close the valve and ignite the gasoline. When the gasoline in the drip cup has nearly all burned, open the needle valve slightly and allow the gasoline to burn slowly in the burner for a


① Regular.


② Roofing.


③ Bottom.

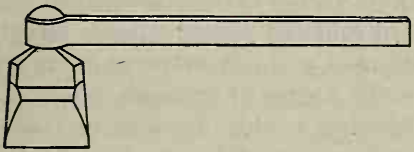

④ Hatchet.

FIGURE 36.—Soldering coppers.

full minute; then open the needle valve to the desired position and increase the pressure in the tank by pumping until the proper flame is produced. If the flame is yellow it is an indication that the burner is not hot enough. When finished close the tank valve and screw in the needle valve just enough to shut off the flame. After the flame has been extinguished open the needle valve slightly as this will prevent enlarging the gas orifice. See that the pump leather is oiled occasionally and release the pressure in the fuel tank when the furnace is not in use.

SECTION II

SOLDERING

Paragraph
General 4
Soft soldering 5
Hard soldering 6
Use of soldering coppers 7
Fluxes 8

4. General.—*a.* Soldering is the process of joining two pieces of metal together by means of an alloy having a lower melting point than that of the metal being joined. Soldering differs from welding in that the metals being joined are not melted and the joining alloy forms a physical joint rather than a mechanical one.

b. The strength of soldered points depends largely upon the nature of the solder being used and the temperature at which the soldering is done; therefore, the degree of strength required for joints must be kept in mind in choosing a solder for a given class of work. A large percent of soldered joints are defective due to improper cleaning and fitting of the parts to be joined. Selection of the proper flux (which is used to remove and prevent oxides) is very important, although most metals can be soldered by the use of zinc-chloride. The metal surfaces must be kept chemically clean and free from oxide throughout the operation. If the base metal is one that oxidizes slowly and is kept at the correct soldering temperature, it is usually sufficient to coat the freshly cleaned surface with tallow, rosin, or some other similar substance. For such soldering the only requirement of the flux is that it should be present during the actual soldering process. If, however, either the metal surface or the solder is covered with an oxide film or coating, some method must be used to remove it. Most of the metal fluxes meet this requirement, thus enabling clean metal surfaces to come together and alloy. In soldering electrical connections and other parts that must be kept free from corrosion, rosin or some other noncorrosive flux should be used.

5. **Soft soldering.**—*a.* The most important points in soft soldering are thorough cleaning of the parts to be joined, careful fitting, and application of the proper flux. The parts may be cleaned by scraping, filing, or brushing with a wire brush. This removes all scale, dirt, and oxides. After the surfaces of the parts to be joined have been cleaned they should be fitted in place, then coated with a suitable flux, after which the application of the hot soldering copper and the proper amount of melted solder to the adjoining parts will cause them to adhere. Unless the metal is new and bright a small additional amount of flux should be applied during the process to remove any oxides that may form and also facilitate melting of the solder previously applied.

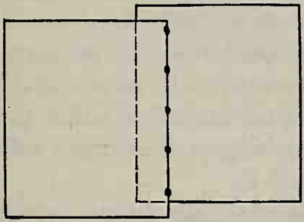


FIGURE 37.—Properly tacked seam.

b. The following procedure applies to the use of soft solder: Unless the joints or seams are riveted, locked, or held by some mechanical method, hold them in position with one hand and with the other take a soldering copper hot enough to melt solder freely. Touch a bar of solder with it and with the drops of solder that adhere tack the seam at a number of points as shown in figure 37 to hold the sheets in position while soldering. Apply a hot, well-tinned soldering copper, with the point extending over the seam on the single thickness of the metal, and the heel or back of the copper over the seam proper, at about a 45° angle. Touch a bar of solder to the hot copper while in this position. As the solder melts, draw the copper slowly along the work, keeping it at an angle and allowing it to draw or sweat the solder the full width of the seam. Make as long a stroke as possible before the soldering copper becomes too cold and when it will no longer melt the solder freely, change it for a hot one. Beginning at the point where the soldering was stopped, hold the hot copper on the seam long enough to remelt the solder at that point, then move it along just fast enough to make a smooth seam.

c. Sweating is a form of soldering and may be accomplished by tinning both surfaces of the pieces to be joined. The pieces are then held together and heated with a soldering copper or blow torch until the solder fuses and begins to run out. The pieces must be kept in close contact until the solder cools and sets.

d. A great variety of solders are available for specific uses; however, they may be classified in a general way as soft and hard solders.

(1) Soft solders melt at comparatively low temperatures and may be used for soldering most commercial metals. Soft solder consists chiefly of tin and lead. It can be obtained in bars, wire, pig, or granulated form. The melting point of tin is about 450° F. and that of lead about 620° F., yet when these two metals are alloyed together in equal proportions to form half and half solder, the melting point drops to about 360° F.

(*a*) The soft solder considered best for airplane work is known as grade A tin and lead solder. It is composed of 99.65 percent tin and lead, alloyed in equal amounts, while the remainder is copper and antimony. The melting point of this solder is 357.8° F. and it is wholly molten at 410° F.

(*b*) Tests of tensile strength based upon cast strips and bars indicate that the higher the tin content (up to 75 percent tin and 25 percent lead) the greater the breaking strength; while in the case of two pieces of tin-plate, or like metals soldered together, the maximum strength is obtained by solder of approximately 50 percent tin and 50 percent lead.

(*c*) Tests prove that the strength of soft-soldered joints is increased if the film of solder between the tinned surfaces of the joint is kept thin. Mechanical pressure should not be used, however, as this has a tendency to weaken the soldered joint during cooling.

(2) High melting point solder contains lead and silver and has a melting point of from 580° F. to 700° F. It is used chiefly when soldering Prestone radiators and other points subject to higher temperatures than lead and tin solders would stand. It may be obtained in wire, bar, and granulated form.

6. Hard soldering.—Hard soldering is a process of soldering with a composition of copper, zince, silver, and tin. This solder is used for soldering band saws; copper, brass, and bronze parts; turbine blades; high pressure and temperature pipe connections; gasoline pipe nipple joints, etc. It is used for this class of soldering because of its strength at comparatively high temperatures and its fatigue resistant properties. Soft soldered gasoline and oil pipe joints, etc., invariably fracture with repeated vibration.

7. Use of soldering coppers.—*a.* Soldering coppers of the proper size and weight must be tinned before they are ready for use. This is accomplished by first heating the copper to a bright red then cleaning the point by filing. If the point is not of the desired shape it may be forged while red hot with a heavy hammer. The copper must then be reheated to a point where it will melt solder and again filed. Sal ammoniac cleans the surface thoroughly and facilitates the adhesion of the solder in tinning, which is accomplished by melting a few drops of solder on a block of sal ammoniac and rubbing the copper over it until the tip is well coated.

b. During the process of soldering, the point of the copper must be kept clean by dipping occasionally in a solution of one part of sal ammoniac to 30 parts of water. This solution should be kept in an earthenware vessel. If sal ammoniac is not available the point of the soldering copper may be tinned and kept clean by the use of powdered rosin. This is accomplished by placing some powdered rosin on a board or brick and rubbing the hot copper on the rosin. Drop some solder on the rosin and rub the copper over this until it is well tinned.

c. A small copper should not be used in soldering a large piece of work, nor should the copper be allowed to become overheated, as excessive temperatures burn the tin off the copper making it necessary to file and retin the tool.

8. Fluxes.—*a.* Fluxes recommended for use with grade A soft solder are—

(1) Rosin, zinc chloride (cut acid), or a rosin-glycerine-steric acid compound. These fluxes may be used with most metals that can be soldered.

(2) Hydrochloric acid (raw acid). For use with galvanized iron and zinc.

b. Fluxes recommended for use with high melting point solder are—

(1) Zinc chloride.

(2) Zinc chloride and powdered sal ammoniac.

c. Fluxes recommended for use with hard solder are—

(1) Powdered borax.

(2) Powdered borax and carbonate of soda.

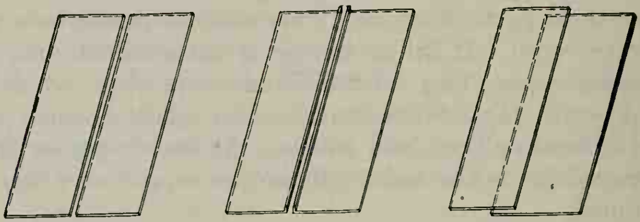
d. Work must be thoroughly cleaned after soldering to remove all traces of flux.

SECTION III

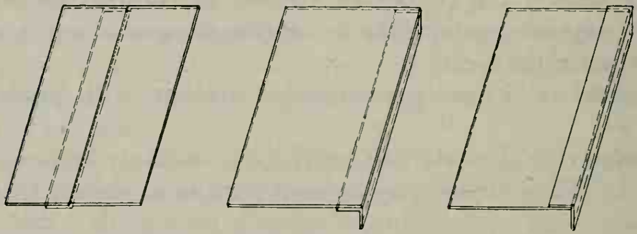
ELEMENTS OF SHEET METAL WORK

Paragraph
General 9
Joints and seams 10
Riveting in tin work 11
Principles of forming 12
Methods of development 13

9. General.—Sheet metal comes in flat stock and must be formed to the desired shape. In order to correctly mark off, cut, and form the object to be made, the workman must be able to visualize the object as it will appear when completed. The pattern is first laid out and calculated. Extra material is then added for seams and the metal cut and formed. Finishing is accomplished by riveting or soldering as required. Most work is laid out directly on the sheet metal and a piece as near the required dimensions as possible should be selected. The work should be laid out in such a manner as to eliminate as much waste as possible.



① Butt joint. ② Flange butt joint. ③ Plain lap seam.



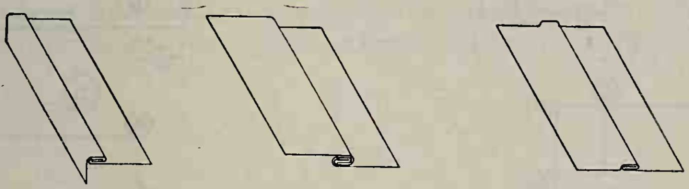
④ Countersunk lap seam. ⑤ Inside lap seam. ⑥ Outside lap seam.

FIGURE 38.—Types of seams and joints.

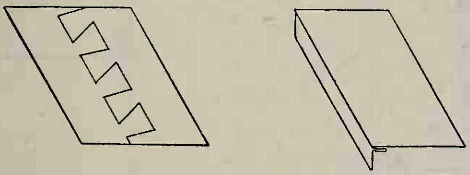
10. Joints and seams.—The methods most commonly used for holding sheet metal together are the butt joints, lap seams, single lock seams (grooved), double seams, and Pittsburgh locks. Other seams that may be used are the double lock seams, concealed locks, and dovetail joints.

a. The butt joint (fig. 38①) is made by bringing the two edges of the metal together with no overlapping and is usually used on heavy sheet or plate to be connected by welding. When thin gage sheets are to be joined by welding a flange butt seam (fig. 38②) is used.

b. A lap seam is made by allowing a portion of the metal (in excess of the net size) to overlap. In making up small articles with this seam, solder is usually used, while for larger seams, where the metal is subjected to strains, rivets should be used and the riveting is often followed by soldering. If for any reason rivets are objectionable on heavy sheets, the seam may be welded. A plain lap seam is shown in figure 38③. For seams which are required to be flush on one side, the portion making the lap is countersunk (see fig. 38④). Inside and outside corner laps are shown in figures 38⑤ and ⑥ and are bent to the desired angle while forming.



① Single lock seam. ② Double lock seam. ③ Double seam.



④ Dovetail joint. ⑤ Concealed lock seam.

FIGURE 39.—Locked seams.

c. The single lock (fig. 39①) is formed on the cornice break or bar folder and is made by turning the edges in opposite directions for the opposing sides to be joined. The sides may then be hooked together and grooved to prevent them from unhooking. The grooving also gives a smoother surface to the work. This lock is generally used as the vertical seam on light metal objects such as buckets, pipes, cans, funnels, tanks, etc., and does not have to be soldered unless the work is to be watertight.

d. The double lock (fig. 39②) is made by turning two complete locks on the opposing ends of the metal and sliding the ends of the seams together. The double lock is sometimes used to avoid soldering and to allow for expansion and contraction.

e. The double seam (fig. 39③) is commonly used in fastening the bottoms on cans, buckets, tanks, etc. This seam may be made either on the folder or burring machine as a single edge and then pounded over a suitable stake with a mallet.

f. The concealed lock is sometimes used on corners and tops of boxes where a flash finish is desired. This seam (fig. 39⑤) is soldered lightly on the outside. A box thus seamed is usually made to fit closely in a recess of other material.

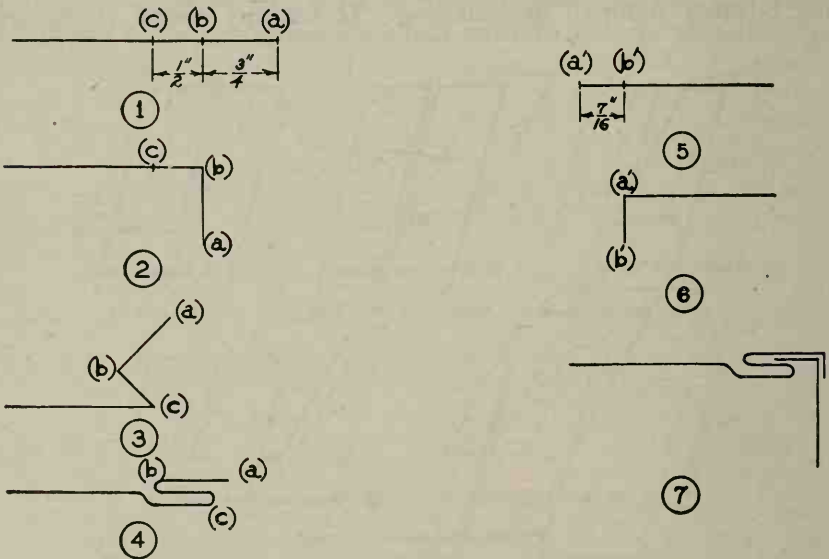


FIGURE 40.—Steps in forming Pittsburgh lock.

g. The dovetail joint (fig. 39④) is often used on the side and bottom seams of heavy copper tanks and is made tight by brazing or silver soldering.

h. The Pittsburgh lock somewhat resembles a large double seam. It is used on large rectangular elbows and pipes or where it would be impractical or impossible to use a stake for double seaming. This joint is formed on the cornice brake before ony other forming is done on the metal. It is very strong and almost airtight. Figure 40 illustrates the various steps in the proper order for forming this lock. Steps ① to ④ are made on the main sheet while steps ⑤ and ⑥ prepare the piece to be added. The finished seam as shown in ⑦ is countersunk so as to make a flush surface on the outside.

i. It is sometimes desirable to stiffen the edges of light-gage metal without the use of a wire or rod. In this case any of the methods shown in figure 41 may be used.

11. Riveting in tin work.—Riveting may be done with a squeeze riveter, pneumatic riveting hammer, or by hand with a rivet set and hammer. Hand riveting is used considerably in general sheet metal work although it is not particularly adapted to aircraft construction and repair to which a separate section is devoted later in the text.

a. For most flat riveting tinners' rivets are used. These rivets have a flat head with a comparatively short stem and may be obtained in black iron, tinned iron, copper, or brass. For any type of rivet other than the flat or flat countersunk head the bucking tool used should be of such a shape as to avoid deforming the rivet. The sheets to be riveted may be punched, drilled, or subpunched and reamed. Most of these rivets are driven cold. In cold riveting, just enough hole clearance should be left to allow the rivet to slip through easily, while hot rivets require more clearance because of the difficulty encountered in handling them.

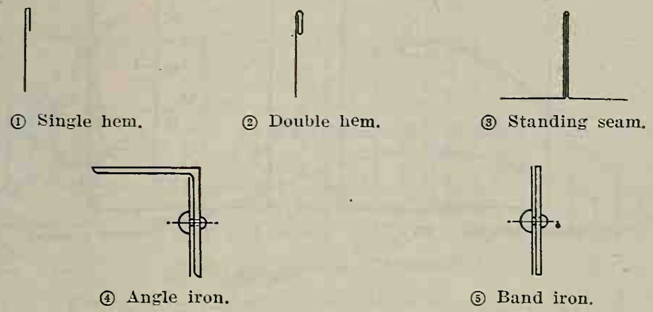

① Single hem. ② Double hem. ③ Standing seam.
④ Angle iron. ⑤ Band iron.

FIGURE 41.—Typical stiffeners.

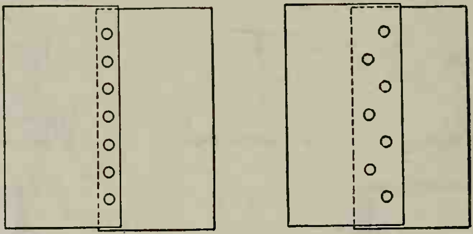
(1) To prevent buckling of the material, when a number of rivets are to be driven, the sheets should be held with clamps, bolts, or sheet metal screws, temporarily spaced at equal intervals along the seam.

(2) The spacing of rivets is determined by the nature of the work and the material used. In general, the minimum distance should be three diameters of the rivet stem with a maximum of eight diameters, while its minimum distance from the edge of the sheet should be two diameters. Rivets placed too close to the edge will cause the metal to stretch and tear, while too great a distance induces buckling and looseness.

(3) The length of a rivet, required to form a head sufficient for

most work depends largely on the clearance between the rivet and the rivet hole, the material from which the rivets are made, and the material being riveted. In general, the length should extend from one to two diameters beyond the material being riveted. The diameter of the rivet should not be less than the combined thickness of the sheets or plates being riveted.

b. Riveting may be single row (fig. 42 ①) or double row (fig. 42 ②) staggered as shown in figure 42. Narrow seams are usually riveted with a single row of rivets in a straight line, while heavy sheets, having a lap of 1 inch or more, are usually riveted with a double row of staggered rivets, and this is especially true when the seam is to be sweated with solder. Unless the rivets are staggered there is a tendency for the hot solder to expand the metal between them, causing gaps and buckles.



① Single riveted. ② Double riveted.

FIGURE 42.—Riveted lap joints.

12. Principles of forming.—Sheet metal is usually formed in cylindrical, square, or rectangular patterns, although many combinations of these basic shapes are also used. Having the desired formation in mind, the pattern for the work is laid out on the metal and the lines marked for forming, making the necessary allowance for laps or seams. The material is then cut out, formed to the desired shape, and the seams made tight by grooving, soldering, or riveting.

a. All regular cylindrical shapes, with either straight or flared sides are formed on the forming rolls unless their finished diameter is less than that of the rolls. When the part is to be wired or given a hemmed edge for stiffening, the operation should be done before forming, although this rule will not apply to some small tapering objects. For sheet thinner than 24 gage the allowance for wiring should be two and one-half times the diameter of the wire to be used, while in heavier material the thickness of the metal should be added to the diameter of the wire.

b. All regular, square, or rectangular shapes are formed either on the brake or over a suitable stake. Where wiring is required it is done after forming. Edges or locks for seaming are usually made while the forming is being done. In the fabrication of fuel tanks, a combination of straight sides with rounded corners is usually desired and in this case the ends may be made first, marking and cutting the corners to the desired radius. The sides or body of the tank are then laid out to fit the ends and this material placed in the brake is formed over wood forms or shaped by hand over a suitable stake.

c. An irregular piece used in sheet metal work to change from one form to another is known as a transition piece. A line drawn through both ends of such a shape would not converge at a common center, as it may be square or oval at one end and round at the other. These pieces may be formed either on the brake or over a stake, depending on their shape and size.

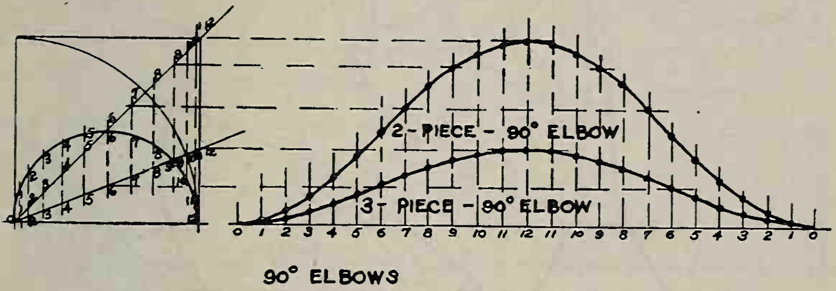


FIGURE 43.—Parallel line development of a 90° elbow.

13. Methods of development.—Sheet metal pattern drafting is founded on the principles of geometry, which relate to the surface of solids, and may be described as the development of surfaces. Sheet metal articles are hollow and are considered in pattern drafting as though they were coverings for solids of the same shape. The different methods for the development of these forms are termed as parallel line development, radial line development, and triangulation.

a. Parallel line development.—This method is used in developing the pattern for any form in which the opposite lines are parallel, such as elbows, tee joints, etc. As there are certain fixed principles that must be applied, the following points, which are illustrated in figure 43, should be carefully observed:

(1) A plan and elevation must first be drawn in which the parallel lines of the solid are shown in their true lengths.

(2) The pattern is obtained from a right view of the article in which the miter lines or lines of intersection are shown.

(3) A stretch-out or girth line is drawn at right angles to the parallel lines of the solid upon which is placed each space contained in the section or plan view.

(4) Measuring lines are drawn at right angles to the stretch-out lines of the pattern.

(5) Lines drawn from points of intersection on the miter line, in the right view, intersecting similarly numbered measuring lines drawn from the stretch-out, will give points showing the outline of the development.

(6) A line traced through the points thus obtained will give the desired pattern.

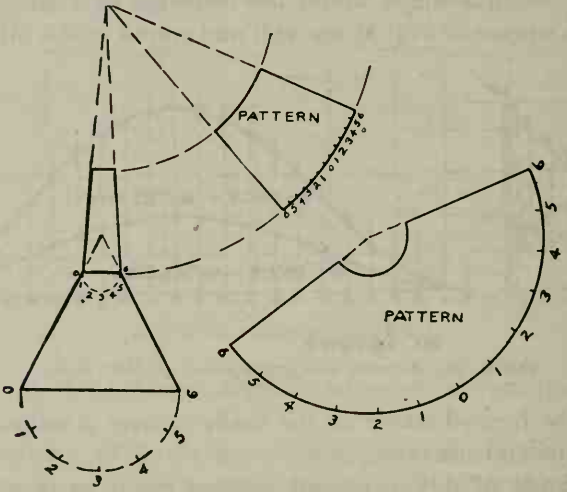


Figure 44.—Radial line development.

b. Radial line development.—This method is used in the lay-out of forms having circles or regular polygons for their bases. Figures with unequal sides that can be described within a circle in which lines drawn from the corners terminate in an apex over the center of the base are also formed by this method. When developing patterns for tapering forms as shown in figure 44, the following points outline the principles by which the development is accomplished.

(1) A drawing must first be made consisting of an elevation showing the true height of the apex and the true length of the radius with which to describe the stretch-out of the pattern.

(2) A plan view is then drawn from which the length of the stretch-out can be obtained.

(3) The stretch-out arc is described with a radius equal to the length of the true edge of the solid.

(4) Points are located on the stretch-out corresponding to the position of the points on the outline of the plan or sectional view.

(5) Measuring lines and edge lines of the pattern are always the radii of the stretch-out arc.

(6) If an irregular or straight line is drawn through any cone in which the radial lines in the elevation intersect, lines must be drawn from these points of intersection, at right angles to the axis, and extended to the side of the cone. These give the true lengths from the apex and are carried to similarly numbered radial lines in the pattern.

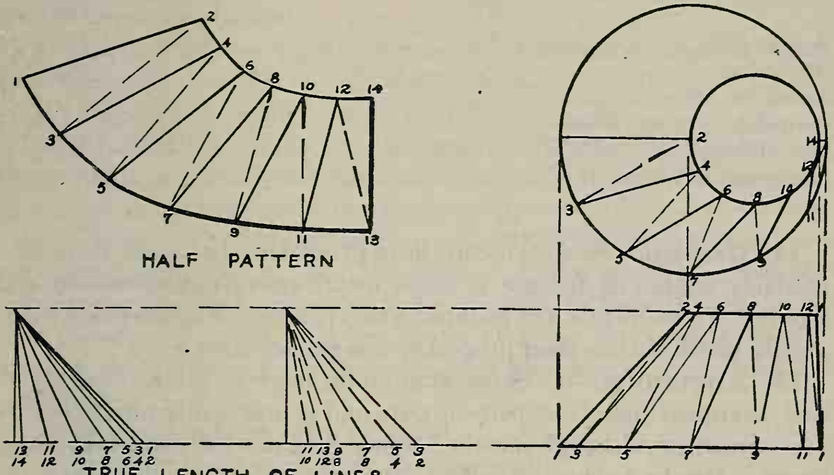


FIGURE 45.—Development by triangulation.

c. Triangulation.—There are a number of irregular forms required in sheet metal work the patterns for which cannot be developed by the regular methods employed in the previous developments. These irregular shapes are so formed that although straight lines can be drawn upon them, the lines would not run parallel to one another nor would they all converge at a common center. Cases of this kind are laid out by means of triangulation as shown in figure 45. The following steps outline this method:

(1) In the development of the pattern for any irregular form the drawing is divided into triangles representing the surface of the object.

(2) From this drawing, the true lengths of the various sides must be found and the triangles constructed from them. As the lengths of the three sides of the triangles are known, their lay-out becomes a simple problem in geometry.

(3) Having found the true length of the sides of such triangles, they may be produced in regular form in the pattern as shown in figure 45.

SECTION IV

PROPERTIES AND USES OF AIRCRAFT SHEET METAL

Paragraph
General ---- 14
Aluminum ---- 15
Aluminum alloys ---- 16
Corrosion-resistant steels ---- 17
Iron and steel ---- 18
Copper and its alloys ---- 19
Lead ---- 20

14. General.—Several metals have properties that make them particularly adaptable for use in sheet metal aircraft construction and repair. These metals are grouped and classified in subsequent paragraphs which outline their properties and general uses.

15. Aluminum.—*a.* Sheet aluminum, used in aircraft construction, is approximately 99 percent pure and is practically unaffected by exposure to air, although certain commercial gases will cause it to deteriorate. Due to its chemical affinity for oxygen, a thin oxide coating is always present on the surface of aluminum and acts as a protective coating for the metal.

b. Aluminum is very light but has no great amount of strength unless alloyed with other metals and for this reason is never used for structural members. It is, however, very valuable in the fabrication of nonstructural units such as fuel and oil tanks, cowling, fairing, seats, etc.

c. Aluminum sheet is obtainable in two standard grades of temper—half hard and dead soft (fully annealed). Half hard aluminum is used wherever possible while dead soft sheet is generally selected for severe forming operations. Annealing is accomplished by heating the metal to between 650° F. and 925° F. and holding it at this temperature from 2 to 5 hours.

d. The properties of aluminum may be outlined as follows:

(1) The hardness is increased by working with a proportional decrease in ductility.

(2) The thermal conductivity is very high, being exceeded only by copper.

(3) The weight is approximately 35 percent that of steel.

(4) The tensile strength ranges from 12,000 to 16,000 pounds per square inch.

(5) It is extremely ductile and may be drawn into wire $\frac{1}{250}$ of an inch in diameter.

(6) It is very malleable and may be rolled into sheets $\frac{17}{10000}$ of an inch in thickness.

(7) It is nonmagnetic and makes a good conductor of electricity.

(8) The melting point is approximately 1,225° F. and it expands about 5 percent in fusion.

(9) It is not affected by the organic acids, resists cold sulfuric and nitric acids, but dissolves in hydrochloric acid.

(10) The alkalies readily decompose it.

16. Aluminum alloys.—*a.* In order to increase the strength of aluminum it is alloyed with various other metals to form the so-called strong alloys for structural use in aircraft.

b. A system of symbols has been standardized to designate the various wrought alloys. In this system a figure is used to indicate the composition of the material and is directly followed by the letter "S", denoting the fact that the material is in the wrought form. Any of the following symbols denoting the temper may then be appended:

(1) O=dead soft or fully annealed.
(2) H=fully cold-worked or hard-wrought.
(3) W=heat treated, then aged at room temperature.
(4) T=heat treated for maximum temper.
(5) A, B, or C preceding the figure indicates a modification of the alloy.

c. Aluminum alloys do not possess the corrosion resistance found in the pure metal and are, therefore, often treated to prevent deterioration when exposed to the atmosphere. The two methods generally used are as follows:

(1) *Anodizing.*—This treatment oxidizes the aluminum alloy and is accomplished by positively charging the material while submerged in a 9.25 percent aqueous solution of chromic acid. After anodizing, the parts must be thoroughly washed in clean, warm water.

(2) *Alclad.*—This is a treatment whereby a coat of commercially pure aluminum is plated over the alloy, making it equal to the pure metal in corrosion resistance.

d. The aluminum and its alloys used in aircraft construction are given in the following table:

TABLE I.—*Approximate composition of aluminum and its alloys*

Alloy No.	Percent				
	Copper	Silicon	Magnesium	Manganese	Aluminum
2 S					99. 5
3 S				1. 2	97. 0
17 S	4. 0		0. 5	. 5	92. 0
Alclad 17 S	4. 0		. 5	. 5	92. 0
A 17 S	2. 5		. 3		95. 0
B 17 S	3. 5		. 3		94. 0
C 17 S	4. 0	1. 2	. 5	. 5	92. 0
24 S	4. 5	. 8		. 8	92. 0
51 S		1. 0	. 6		96. 0
52 S			2. 5		96. 25

e. Identification of stock.—Most aluminum base sheets are marked with the specification number on approximately every square foot of material. If for any reason this identification is not present it is possible to separate the heat treatable alloys from the nonheat treatable alloys by immersing a sample of the material in a 10 percent solution of caustic soda (sodium hydroxide). The heat treatable alloys will turn black due to the copper content whereas the others will remain bright. In the case of Alclad the surface will remain bright, but there will be a dark area in the center when viewed from the edge of a cut.

(1) The identification of bars, tubes, and wire by specification number is impracticable and a code marking, consisting of painted stripes, has been established. This is also used for sheets that do not have the specification numbers stamped on the surface. Three stripes, one in the middle and one near each end, are painted around each bar, tube, etc., and across one face of each sheet that is not otherwise identified. Each stripe should be approximately 2 inches wide. The colors corresponding to the various alloys are given in Table II.

(2) Rockwell hardness tests may be used to distinguish between annealed and cold-worked or heat treated material but are not satisfactory for alloy identification. The values given in Table III are obtained with the $1/8$-inch ball and 100 kg. load, reading the red figures on the dial. Hardness readings are not reliable for materials less than $1/64$ of an inch in thickness.

TABLE II.—*Color identification chart for aluminum alloys*

Alloy No.	Specification	Color
2	QQ-A-411 57-151-1 WW-T-783	White.
17	QQ-A-351 QQ-A-353 57-152-2 WW-T-786 57-187-2	Yellow.
24	QQ-A-355 11067 QQ-A-354 10235 QQ-A-367	Insignia red.
52	QQ-A-318 57-187-3	Purple.

TABLE III.—*Rockwell hardness values for the various aluminum alloys*

Alloy No.	Temper	Rockwell E (minimum)	Rockwell E (maximum)
2	Soft		5
2	Half-hard	20	
52	Soft		65
52	Half-hard	70	
17	Annealed		70
17	Heat treated [1]	90	
24	Annealed		70
24	Heat treated [1]	95	

[1] The values for heat treated material represent alloys that have been quenched and aged at room temperature for not less than 4 days, as explained under Heat treatment.

f. Heat treatment.—The heating of aluminum alloys for this process is done in an electric air furnace or a nitrate bath heated by oil, gas, or electricity. When the latter method is used, the bath consists of a mixture of equal parts of potassium nitrate and sodium nitrate. The melting point of this bath is approximately 450° F. Additions to the bath should be made of a similar mixture and no other salt or chemical added as cyanide salts may cause serious explosions, and common salt (sodium chloride) will raise the melting point of the bath very rapidly. Circulation of the heating medium in either of the above methods is desirable. In the case of the nitrate bath, alternate raising and lowering of the metal charge causes circulation, but care must be exercised that no part of the metal is raised above the surface. The salt bath must not be used for assemblies or parts that cannot be thoroughly washed to remove the bath solution. All heating units must be equipped with an accurate temperature controlling device, and a temperature survey should be made of the furnace or bath at frequent intervals to make sure that there are no local hot spots that might cause overheating of the aluminum alloy being treated. Magnesium or magnesium alloys must never be placed in a hot salt bath as an explosion may occur.

(1) Aluminum alloys are annealed by heating at the temperatures specified in Table IV, followed by cooling in the air or a furnace.

TABLE IV.—*Heat treating procedure for aluminum alloys*

Alloy No.	Annealing temperature ° F.	Solution treatment		Aging		Tensile strength (pounds per square inch)
		Temperature ° F.	Quench	Temperature ° F.	Time (hours)	
2[1]	625–700					12, 000
3[1]	725–775					19, 000
17	650–800	925–950	Cold water	Room	16–24	55, 000
24	650–800	910–930	Cold water	Room	16–24	62, 000
52[1]	650–800					31, 000

[1] Alloys 2, 3, and 52 are nonheat treatable, hence no hardening or aging data are given.

The length of time for heating depends upon the thickness of the material and the amount of cold-working to be performed on the piece. The time for annealing should be made as short as possible as a long period causes grain growth and loss in ductility. In the case of Alclad parts, the copper constituent tends to diffuse through the pure aluminum coatings when heated too long which reduces the effectiveness of the pure aluminum as a corrosion-resistant covering. Table V gives the minimum time of soaking (holding at a specified temperature) for the various thicknesses of metal.

(2) The process of hardening aluminum alloys consists of heating, quenching, and aging.

TABLE V.—*Time required for solution treatment*

Thickness of material (inches)	Minimum time of soaking for solution treatment (minutes)			
	Air furance		Salt bath	
	Alloy 17	Alloy 24	Alloy 17	Alloy 24
Up to 1/32	10	20	10	20
1/32–1/16	20	30	15	20
1/16–1/8	30	30	20	30
1/8–3/16	40	40	20	40
3/16–1/4	60	60	20	50
1/4–1/2	90	90	30	60
1/2–1	120	120	60	60
Over 1	(1)	(1)	(1)	(1)

(1) 3 hours for each inch of diameter or thickness.

(*a*) *Heating.*—Bars, sheets, tubes, etc., are heated in the salt bath or furnace for the length of time and at the temperatures indicated in Tables IV and V. The time stated is actual time at the specific temperature for all parts of the charge in a noncirculating medium. In case forced circulation is used, the time may be reduced and amount determined by actual test.

(*b*) *Quenching.*—Aluminum alloys should be quenched in cold water although complicated castings may be quenched in hot water or hot soapsuds to reduce warping. The effect of quenching is to retain the alloying constituents of the material in solid solution. Aluminum alloys cool repidly when removed from the furnace atmosphere, therefore, quenching tanks must be located close to the furnace and the transfer from furnace to tank handled with maximum speed. All parts of the charge must be completely immersed. The two operations of heating and quenching are designated as the solution treatment. This treatment increases the strength and hardness over that of the annealed condition, but the maximum strength and hardness may only be obtained through aging. In either case, the ductility is not appreciably affected. Parts fabricated from Alclad may be cooled in air if water quenching causes distortion that cannot be corrected by reforming before the aging is complete.

(*c*) *Aging.*—After the solution treatment the material will tend to harden gradually and after a period of time (approximately 4 days), dependent on the composition and the thickness of the material, it will reach its maximum strength and hardness. Certain alloys will not age at room temperature but must be given an aging treatment at an elevated temperature as indicated in Table IV to obtain the maximum strength. Artificial aging can be done in an electric furnace or enameling oven although aging at elevated temperatures impairs the corrosion resistance of sheets and tubes made from the alloy group between 17 and 24, inclusive. These alloys are generally formed in sections thin enough that normal aging at room temperature is satisfactory thereby eliminating the need for artificial treatment.

(*d*) *Washing.*—When a salt bath is used for heat treatment of aluminum alloys, all traces of salt must be removed by washing in warm water, following the quenching process. The cleaning should be done rapidly so that the parts will be in warm water the shortest practicable time. A dark stain sometimes remains after washing but this is not harmful to the strength of the material.

g. Hot working.—Local heating must never be applied to facilitate bending, swaging, flattening, or expanding operations on heat treated aluminum alloys as it is impossible to control the temperature closely enough to prevent damage to the metal. A torch with a large, soft flame is sometimes played over the surface of cold-worked aluminum or the nonheat treatable alloys to anneal locally for bending or forming. This practice is permissible when it is impractical to anneal in a furnace or bath. The metal should not be heated above a temperature that will just char a resinous pine stick.

h. Cold working.—The precautions to be taken in the fabrication of aluminum alloys depend upon the thickness of the material and the degree of working required. The most severe working must be done while the material is in the annealed condition, while less severe operations may be accomplished on heat treated material immediately after quenching and before age hardening has taken place (the time limit being 1½ to 2 hours). The general effect of cold-working is to increase the strength and hardness and decrease the ductility. Whenever bending operations are performed on bar or sheet the bending radius must not be less than that given in Table VI. However, if the thickness of the bar or sheet exceeds ¼ inch and the bend exceeds 15°, the material must be annealed before bending. Care must also be exercised to prevent deep scratches or abrasions on either the inside or outside surface of the bend. If a cornice brake is used to form sections, it is advisable to place a thin sheet of soft metal over the brake jaw to form the inside radius of the section.

TABLE VI.—*Minimum radii of 90° bends for aluminum alloy sheets (t=thickness of sheet)*

Specifications	Temper	Sheet thickness in inches			
		0. 01–0. 02	0. 02–0. 07	0. 07–0. 15	0. 15–0. 38
QQ–A–318	Soft	0	0	0	½t
QQ–A–318	½ hard	½t	1t	1t	2t
QQ–A–353	Annealed	0	0	½t	1t
QQ–A–353	Heat treated	1½t	3t	4t	5t
QQ–A–355 and 11067	Annealed	0	0	½t	1t
QQ–A–355 and 11067	Heat treated	2t	4t	5t	6t
57–151–1	Soft	0	0	0	0
57–151–1	½ hard	0	0	0	½t

Aluminum alloy may be cut, drilled, or machined either in its annealed or hardened condition. All tools should be kept sufficiently sharp to cut clean and smooth. Holes in thin sheets may be punched if the material is not heated or deformed by the operation.

i. Uses of the most common alloys.—Alloy number 24, plain, and with Alclad coating, is used for heat treated parts, airfoil covering, and fittings. It is stronger and may be used as a substitute for number 17 alloy. Alloy number 52 is used extensively for fuel lines, and has also been used in the past for fuel tanks, wing tips, etc. When replacing or patching sections of aluminum sheet, number 52 alloy should be used. In such cases, the repairs must be made with sheet stock one gage heavier than that used originally. The 52 alloy welds satisfactorily to aluminum sheet. Number 4 alloy has been used quite extensively for fuel and oil piping but is gradually being replaced by number 52. Number 4 alloy, in the form of sheets, is also used for ring cowling.

17. Corrosion-resistant steels.—Corrosion- and heat-resistant steel has the following chemical composition: 17.0–20.0 percent chromium; 8.0–10.0 percent nickel; 0.07 percent carbon (maximum); 0.20–0.70 percent manganese; 0.03 percent phosphorus (maximum); 0.4 percent sulfur (maximum); 0.70 percent silicon (maximum); 0.50 percent copper (maximum); and the rest iron. It is marketed under various trade names such as Carpenters' stainless steel, Resistal KA2, 18–8 Enduro, and Allegheny metal.

a. A typical example of corrosion-resistant steel is Allegheny metal. Its chemical composition is approximately 18 percent chromium, 8 percent nickel, and the rest iron, with a very low carbon content. At the present time its principal use in aircraft is in the fabrication of exhaust stacks, firewalls, manifolds, collector rings, ammunition boxes, and flare cans. Because of its resistance to corrosion from hot gases and various acids, it has a decided advantage over ordinary steel for such work. In the annealed condition, Allegheny metal has a tensile strength of approximately 90,000 pounds per square inch and its melting point is between 2,606° F. and 2,679° F. It is nonmagnetic in the annealed condition but becomes slightly magnetic after excessive working. It cannot be heat treated to produce definite physical properties and such properties can be imparted only through hot- or cold-working processes. Allegheny metal can be welded or soldered and may be formed, drawn, or spun.

(1) Owing to its tendency to work-harden and crack under strain, corrosion-resistant steel should not be scratched at any time and lay-out work must be accomplished by marking with a soft pencil. In shearing this metal, about twice the amount of power is required as for mild steel. The shear blades should have a very close adjustment so that the metal will not be drawn over the bottom blade and work-harden before the actual shearing begins.

(*a*) In punching there should be the same close adjustment between the punch and die regardless of the thickness of the metal. If there is too great a clearance, the metal will be drawn over the edge, work-harden, and bring excessive strain on the punch.

(*b*) Drilling should be done with a high speed drill bit and best results are obtained by the use of special drills designed for corrosion-resistant steel and ground at a 140° included angle. Some of these special drills have an offset point while others have a chip curler in the flutes. When an ordinary twist drill is used it should be ground somewhat flatter than the standard drill point. The speed of the drill for corrosion-resistant steel should be about one-half that used in drilling mild steel and should never exceed 750 r.p.m. The drill should be dipped in water after each hole. Laying out of the holes should be done with a triangular pointed center punch and care must be used to prevent work-hardening the metal. Due to this work-hardening characteristic, it is necessary to apply sufficient pressure on the drill to make it cut at all times and the material should be drilled on a backing plate, such as cast iron, that is hard enough to permit the drill to cut all the way through without pushing the material away from the drill point. The high speed of many portable electric hand drills builds up temperatures very rapidly which results in burning the point of the drill. It is, therefore, advisable to spot the drill before applying the power and also to make sure that when the power is turned on pressure is being exerted. If the drill is allowed to make a few revolutions without cutting, it work-hardens the material to such an extent that continued drilling is impossible. When drilling deep holes the use of a compound made up of 1 pound of sulfur to 1 gallon of lard oil will prove satisfactory.

(*c*) In sawing, a high speed hack saw blade of the wavy tooth type (32 teeth to the inch) should be used for light gages. Heavier material, such as plate and bars, requires the use of a blade having less teeth to the inch. As soon as the metal contacts the saw blade it should be forced to start cutting. Another method of cutting light gage metal is by the use of a rubber bonded cut-off wheel mounted on a grinder turning at high speed.

(*d*) As a rule this metal is much more difficult to draw or spin than metals which are commonly used, such as copper, brass, and aluminum. The speed for spinning should be cut down from one-fourth to one-half of that for copper. In either drawing or spinning, good work depends greatly on the use of a proper lubricant. White lead and linseed oil, mixed to the consistency of a medium thick paste, is considered one of the best lubricants for this purpose.

(2) The fact that corrosion-resistant steel increases in strength very rapidly under the influence of cold-working, such as forming, drawing, and spinning, makes it necessary to limit the amount done between annealing operations. If the strain set up by cold-working nears or exceeds the endurance limits of the metal the piece is apt to fracture after it has been worked and before it has been annealed. A very good method for determining whether the danger point has been reached in cold-working is to test the piece with a strong magnet. If the piece shows any magnetism, the amount of working should be reduced on the next piece to a point where no magnetism is apparent. Inasmuch as the corrosion-resistant metals are in their best condition to withstand corrosion when free from work strains, it is recommended that the metal be annealed after all excessive working operations.

(3) Corrosion-resistant steel can be soldered but there are certain precautions to be taken in order to get proper adhesion. When the metal is highly polished it is quite resistant to hydrochloric acid, which is the base of most soldering fluxes. Some of the best results may be obtained by first applying full strength hydrochloric acid and allowing it to remain for several minutes to etch the surface of

the metal. After this has been done, zinc chloride flux is applied in the regular manner without removing the acid. The fact that corrosion-resistant steel has approximately 48 percent of the thermal conductivity of wrought iron makes it necessary to use a larger soldering copper than is required for steel, etc. A longer time is also required to get the metal to the proper temperature although excessive heating will cause the solder to become brittle. To prevent buckling due to the high expansion coefficient of the metal it is sometimes necessary to use chill plates, preferably of copper, which will keep the temperature from extending out over the surface of the sheet. Immediately after soldering, the parts should be washed to prevent any further action of the acid. Either ammonia water, or water in which a liberal amount of yellow laundry soap and soda has been dissolved, may be used. Because of the physical properties of the metal which include a very high expansion coefficient, it is desirable not to depend on soldering for anything except a tight joint. The required strength may be obtained by riveting or spot-welding. It is often found that locked seams and soldered joints in the metal do not remain tight over a long period of time; this is due to its work-hardening characteristics which tend to cause it to spring back slightly.

(4) Corrosion-resistant steel resists discoloration and corrosion much better when the surface is highly finished and free from grinding wheel marks, etc. When it is considered advisable or necessary to do rough grinding it is preferable to use a soft, free cutting wheel that will not fill up. The use of such a wheel will keep the temperature to a minimum and therefore overcome the tendency to buckle. Grinding and polishing may be carried to whatever degree is desired by using emery as fine as 200 mesh. Buffing is best accomplished by the use of green chrome rouge.

b. Nickel-chromium-iron alloy (*Inconel*).—This material, although differing somewhat from stainless steel, may be classed with it due to the similarity in characteristics. Inconel has the following chemical composition: 0.05 percent copper, 75.0 percent nickel, 9.0 percent iron, 12.0 to 15 percent chromium, 1.0 percent manganese, 0.15 percent carbon, and 0.5 percent silicon. Cold-rolled sheet and strip are designated as type III, class A, and will be referred to in the following description.

(1) The tensile strength is higher than that of Allegheny metal. being 125,000 pounds per square inch, and it is well suited for the fabrication of parts subject to high temperature (from 800° F. to 1,600° F.).

(2) Inconel welds readily and is highly resistant to salt water, etc.

The working qualities are quite similar to those of the corrosion-resistant steels and general operations are carried on in the same manner.

(3) Because of a close similarity in appearance between Inconel and Allegheny metal, a distinguishing test may sometimes be necessary and is outlined as follows:

Dissolve 10 grams of cupric chloride in 100 cc. of hydrochloric acid. With a medicine dropper, place one drop of the solution on the sample to be tested and allow it to remain in contact with the metal for 2 minutes. At the end of this time slowly add three or four drops of water to the solution on the metal (one drop at a time), then wash and dry the sample. If the metal is stainless steel the copper in the cupric chloride solution will be deposited on the metal leaving a copper colored spot, whereas if the sample is Inconel a white spot will be present.

18. Iron and steel.—Most applications of ferrous metals, with the exception of the corrosion-resistant steels, are limited to tubing and plate. This sheet is, however, used to some extent in the following forms:

a. Galvanized iron or zinc coated steel.—This material is employed mainly for the construction of tanks, etc., for use in the shop, and consists of black iron sheet thinly coated with zinc.

b. Tin plate.—Sheets used in making tin plate are rolled from high quality iron or soft steel. The sheet is coated with molten tin and the coating is controlled in thickness by means of rolls. Sheet of this type is fully annealed and may be used for small containers, etc.

c. Terneplate.—Terneplate is very similar to tin plate being iron coated with a mixture of tin and lead. Although commonly referred to as roofer's tin it has been used, in some instances, for fuel and oil tanks.

19. Copper and its alloys.—Copper, in its commercially pure form, is used in making gaskets, radiators, fuel and oil lines, etc. It is extremely ductile and forms an excellent conductor for both heat and electricity. Several alloys of copper are employed for aircraft construction in the sheet form and may be described as follows:

a. Sheet brass.—This material is an alloy of copper and zinc. Although the proportions vary considerably, the better grades contain approximately 75 percent copper and 25 percent zinc. When the zinc content becomes too great the brass is apt to be very brittle.

(1) Sheet brass is manufactured in various degrees of hardness, that is, ¼ hard, ½ hard, ¾ hard, and full hard tempers. The degree of hardness is determined by the rolling of the sheets after the last annealing. When the sheet is reduced in thickness by one gage number, it is graded as ¼ hard; when rolled two gages thinner, ½

hard; when rolled three gages thinner, ¾ hard; and when rolled four gages thinner, full hard.

(2) Sheet brass which can be obtained in the various tempers is used for some fuel tanks and expansion tanks for radiators. It is easily formed and soldered but should not be bent to any extent while hot as this will cause the metal to crack along the bend lines. It has a minimum tensile strength of approximately 40,000 pounds per square inch and melts at 1,500° F. to 1,700 ° F.

b. Copper-nickel alloy (*Monel*).—Monel metal is a trade name for an alloy containing approximately 67 percent nickel, 28 percent copper, and 5 percent other elements, chiefly iron and manganese. It is white, malleable, ductile, and noncorrodible. It solders easily and has good forming qualities but is somewhat harder to shear or drill than mild steel. Monel metal has a tensile strength of 65,000 to 130,000 pounds per square inch and a melting point of approximately 2,420° F. Monel sheets are used for floats on some seaplanes and for the manufacture of tanks, boxes, etc., where the metal is apt to come in contact with acids.

c. Copper-silicon-manganese alloy (*Everdure*).—This material has a chemical composition of 1 to 5 percent silicon, 1.50 percent manganese, 2.5 percent iron (maximum), 2 percent tin (maximum), 5 percent zinc (maximum), and 0.50 percent impurities (maximum). Everdure sheet has a tensile strength of approximately 53,700 pounds per square inch in the annealed condition and 92,870 pounds in the full hard condition. Its melting point is 1,850° F. and it may be welded, brazed, or soldered. This metal is resistant to corrosion by salt water and a number of acids. As it is noncorrosive, easily worked, and free from work-hardening, it is used for tanks and containers where weight is not a factor. Everdure is about three times the weight of aluminum.

20. Lead.—Because of the extremely low strength-weight ratio, lead is not used in aircraft construction but is required to a certain extent in the shop, for use in the connection of photographic and plating tanks, acid containers, etc.

a. Sheet used for this purpose is generally grade A which is 99.9 percent pure. This material has a tensile strength of from 1,000 to 3,000 pounds per square inch and may be soldered or welded.

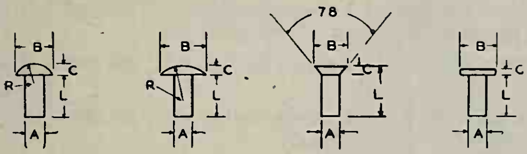
b. The thickness of lead sheet is commonly expressed in terms of its weight per square foot, for example, a $\frac{1}{16}$-inch sheet weighs 4 pounds per square foot and is referred to as 4-pound sheet.

SECTION V

AIRCRAFT SHEET-METAL RIVETS, SCREWS, AND MISCELLANEOUS FASTENERS

Paragraph
General 21
Rivets and riveting 22
Types and uses of sheet-metal screws 23
Spring sheet holders 24
Self-locking nuts 25
Dzus fasteners 26

21. General.—Both rivets and sheet-metal screws are used to a large extent in the construction of modern aircraft. Most of the rivets employed in the structural members are heat treated aluminum alloy of the solid shank type, although iron or steel rivets may be used for some special joints. Steel sheet-metal screws and other special fasteners, although not adapted for use in the primary structure, have many applications in the attachment of cowling, etc.



	DIAMETER	WIDTH	HEAD DEPTH	HEAD RADIUS
KIND	A	B	C	R
ROUND HEAD	A	2.00 A	75 A	1.042 A
BRAZIER HEAD	A	2.50 A	.50 A	1.8125 A
CTSK. HEAD	A	1.81 A	50 A	
FLAT HEAD	A.	2.00 A	.40 A	

FIGURE 46.—Types of rivets.

22. Rivets and riveting.—Riveting, as applied to aircraft structures, differs in many ways from the ordinary riveting of steel or iron. This operation must always be done in a way to produce the greatest strength possible, and any distortion of the material must be avoided.

a. Types of rivets.—The factors governing the selection of rivets depend largely on the job to be done and the location of the seam. Figure 46 shows the common types of solid shank rivets and Table VII gives their general specifications.

In many cases where the rivets are to be subjected to shear stresses only, the appearance of the heads may well be the determining factor.

However, where it is possible that some tensile stress may be induced in the rivet, other points must be considered. In such cases a type of rivet should be used in which the height or thickness of the head is not less than one-half the diameter of the rivet shank.

TABLE VII.—*Rivet specifications*

Type	Material	Identification	Shearing strength (pounds per square inch)	Remarks
A	Aluminum alloy No. 2.	Plain	10, 000	Do not heat treat before using.
AD	Aluminum alloy No. A-17S.	1 dimple in head	25, 000	Do.
D	Aluminum alloy No. 17S.	1 raised tit on head	30, 000	Heat treat before using.
DD	Aluminum alloy No. 24S.	2 raised dashes on head.	35, 000	Do.
	Iron (cadmium plated).	Plain	35, 000	

(1) *Round head.*—This type of rivet is used in relatively thick sheets where strength is required. The size of the head is such that it covers sufficient area to strengthen the sheet around the hole and at the same time offers considerable resistance to tension.

(2) *Brazier head.*—The brazier head type is used extensively for the riveting of thin sheet (skin) exposed to the slip stream as it offers little resistance to the air. The large diameter of the head makes it particularly adaptable for use in thin sections.

(3) *Countersunk head.*—This type is used for riveting thick sheets over which other plates must fit. Countersunk head rivets may also be used, in some cases, for riveting thin sheet exposed to the slip stream.

(4) *Flat head.*—The flat head type of rivet is sometimes used for internal riveting where increased clearance is required.

(5) *Special rivets.*—The two special rivets used to a certain extent in aircraft construction are as follows:

(*a*) *Thompson steel tubular rivet* (fig. 47).—These rivets are not in the true sense tubular. The portion of the rivet shank through the material is solid and is only drilled to a depth sufficient for heading or up-setting. For this reason, the lengths must be very carefully matched in relation to the thickness of the materials through which they go.

(*b*) *Goodrich rivnuts* (fig. 48).—Rivnuts are threaded rivets manufactured from alloy number 53. Rivnuts are used in places that are impossible to reach with a bucking iron, such as for the attachment of deicing boots, etc. The rivet is hollow and the end opposite the head has an itnernal thread for approximately one-half its length. The remaining length is counterbored to a somewhat larger diameter than the thread. The rivet is headed by means of a tool with a threaded mandrel which is screwed into the threaded portion of the rivet. The tool bears against the head of the rivet and withdraws the mandrel which upsets the counterbored portion as shown in figure 48. Table VIII gives the general specifications for its use.

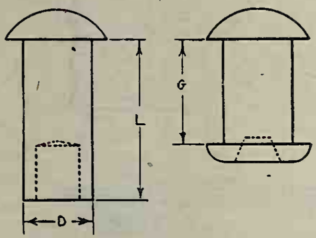


FIGURE 47.—Thompson rivet.

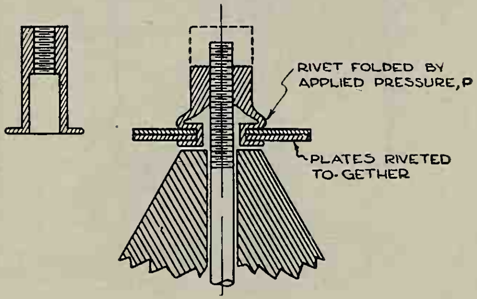


FIGURE 48.—Goodrich Rivnut.

TABLE VIII.—*Specifications for the use of Goodrich Rivnuts*

Type	Rivet length (inches)	Total thickness of joint (inches)		Type of screw	
		Maximum	Minimum	Round head	Flat head
Open end	3/8	0. 050	0. 020	AN 515-6-5	AN 505-6-5
	7/16	0. 070	0. 050	AN 515-6-6	AN 505-6-6
	1/2	0. 130	0. 070	AN 515-6-7	AN 505-6-7
Blind end	9/16	0. 130	0. 070	AN 515-6-7	AN 505-6-7

b. *Heat treatment of rivets.*—Aluminum-alloy rivets are heat treated in the same manner as the sheet stock described in paragraph 16. Rivets manufactured from 2, A-17, and 53 alloys have been heat treated by the manufacturer and no further treatment is necessary. In case the marking on the head is indistinct the rivets may be identified as indicated in paragraph 16. Heat treated rivets may be identified by Rockwell hardness. To do this the rivet should be supported in a V-block and the hardness reading with a $\frac{1}{16}$-inch ball and 60-kg. load. A hardness of over 75 indicates a heat treated rivet. For joining highly stressed parts, either heat treated aluminum-alloy or cadmium-plated soft iron rivets may be used. Aluminum or annealed-aluminum-alloy rivets must never be used for joining highly stressed parts but may be used for cowling, tanks, etc.

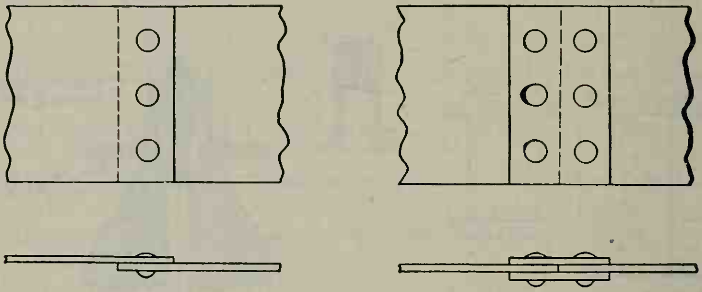

① Lap. ② Butt.

FIGURE 49.—Types of riveted joints.

Aluminum alloy rivets 17 and 24 must never be headed over when in the hardened condition. Driving is done immediately after quenching unless the rivets are held at a low temperature.

c. Types of joints (fig. 49).—The two standard joints used in aircraft construction are the lap joint and the butt joint. Either type may be made with one or more rows of rivets. In joints using more than one row the rivets are usually staggered to distribute the stresses.

d. General riveting procedure.—A large percentage of the riveting of airplane structures is done on thin gage aluminum alloy and the work must be so accomplished that the material is not distorted by hammer blows or injured with the riveting tools. Most aircraft riveting is done by up-setting or heading the rivets against a bucking tool instead of striking the shank with a hammer.

(1) To prevent deforming of its head a rivet set must be selected to fit each type. The depth of this set must be such that it does not touch the material being riveted.

(2) Parts riveted together should be heat treated before riveting since heat treating after this process causes warping. This is also

necessary when assemblies are heated in a salt bath as the salt cannot be entirely washed out of the cracks.

(3) Rivets of a diameter smaller than 3/32-inch must not be used for any structural parts, control parts, wing covering, cowling, or similar sections of the airplane.

(4) When solid rivets go completely through hollow tubes their diameter should be at least one-eighth of the outside diameter of the tube. Rivets through hollow tubes which are loaded only in shear should be hammered just enough to form a small head. No attempt should be made to form the standard round head as the amount of hammering required often causes the rivet to buckle inside the tube, with resultant injury to the member. Correct and incorrect examples of this type of installation are shown in figure 50.

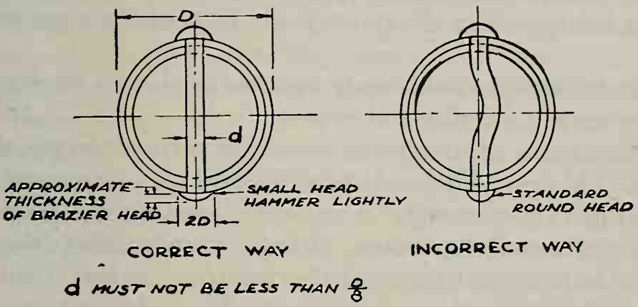

D
d
APPROXIMATE THICKNESS OF BRAZIER HEAD
SMALL HEAD HAMMER LIGHTLY
2D
STANDARD ROUND HEAD
CORRECT WAY
INCORRECT WAY
d MUST NOT BE LESS THAN D/8

FIGURE 50.—Correct and incorrect method of riveting through tubular structures.

(5) Aluminum-alloy rivets must never be used in tension for structural, control, or other critical parts of the airplane. Whenever such an installation is required, cadmium-plated iron rivets must be used.

(6) The use of hollow rivets in joining highly stressed parts is only permitted when solid rivets cannot be driven because of the inaccessibility of the end for bucking or driving.

(7) The selection of the proper rivet for the various operations is very important and must be given careful consideration. The following table gives the application of standard rivets.

(8) The rivets must be of the proper length for the total thickness of the pieces being riveted. Ordinarily from 1½ to 2 times the diameter of the rivet is about the right amount for the rivet shank to protrude through the material to form the head. For heavy material, such as plates or fittings, from 2 to 2½ diameters may be used. Where the two edges of thin sheet are lapped and riveted together, about one diameter of the rivet will prove sufficient.

Table IX.—*Selection of rivets*

Rivet type	Use
A	Parts fabricated from 2S and 3S alloy.
AD	Parts fabricated from 17S and 24S alloys.
D	Parts fabricated from 17S and 24S alloys.
DD	Parts fabricated from 24S alloy and as a substitute for types AD and D rivets.
Iron	Parts where rivets are subject to tensional stresses.

(*a*) The rivet should not be too loose in the hole as this condition will cause it to bend over while being headed, and the shank will not be sufficiently expanded to completely fill the hole. A drill from .002 to .004 inch larger than the rivet should be used for sheet and plate riveting.

(*b*) Pieces should be held firmly together by clamps, screws, or bolts while they are being drilled and riveted.

(*c*) Where rivets are headed on the inside of the structure, the bucking tool is held against the end of the rivet shank. Care must be exercised during this operation to prevent unseating the rivet by the application of too much pressure. For the first few blows the bucking tool should be held lightly against the rivet shank so that it will receive the impact of the blow through the rivet. The tool must be held square with the rivet to avoid turning it over.

(*d*) Only a sufficient number of blows should be struck to properly up-set a rivet. The blows must be as uniform as possible; not too hard or too light.

e. Spacing and diameter of rivets.—There are no specific rules which are applicable to every case or type of riveting. There are, however, certain general rules which should be understood and followed.

(1) Rivets are never placed closer than two diameters of the rivet measured from the edge of the sheet or plate, to the center of the rivet hole.

(2) The spacing between rivets, when in rows, depends upon several factors, principally, the thickness of the sheet, the diameter of the rivets, and the manner in which the sheet will be stressed. This spacing is seldom less than four diameters of the rivet, measured between the centers of the rivet holes. Rivets spaced four diameters apart are found in certain seams of monocoque and semimonocoque fuselages, webs of built-up spars, various plates or fittings, and floats or pontoons.

(3) Where there are two rows of rivets they are usually staggered. The transverse pitch or distance between rows should be slightly less than the pitch of the rivets, 75 percent of the rivet pitch being the usual practice.

(4) An average spacing or pitch of rivets in the cover or skin of most structures, except at highly stressed joints, will be from 6 to 12 diameters of the rivet.

(5) The best practice in repair jobs, when possible, is to make the pitch of the rivets equal to those in the original structure.

(6) The spacing of rivets in tubes, when they are spliced, or when the rivets go completely through them, are as follows:

(*a*) When adjacent rivets are at right angles they are placed from four to seven diameters apart. The first rivet on each side of the joint should be not less than two and one-half times the diameter of the rivet from the end of the tubes, and the last rivet not less than two diameters from the ends of the sleeve.

(*b*) When the rivets are in line they should be spaced from five to seven diameters apart.

(7) Practically all of the rivets used on the skin covering of wings, control surfaces, and fuselages are ⅛ inch, although certain seams or sections may require the use of larger or smaller diameters.

(8) Rivets smaller than $\frac{3}{32}$ of an inch in diameter should not be used for any structural parts which carry stresses and very few rivets are used which are over $\frac{5}{16}$ of an inch in diameter.

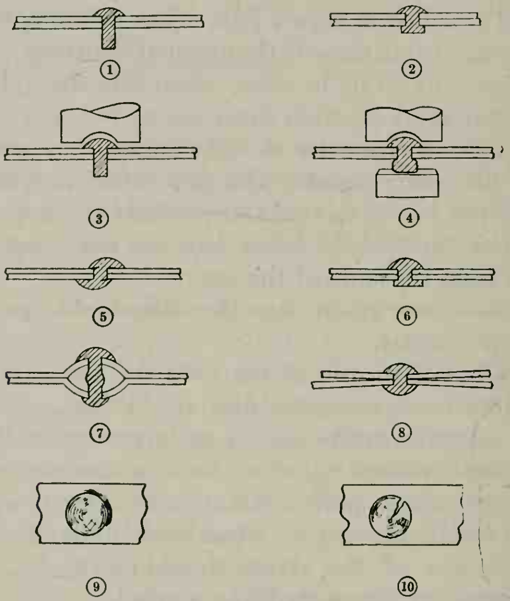
(*a*) The diameter of the rivets should never be less than the combined thickness of the parts being riveted.

(*b*) In tubular members, where the rivets go completely through the tubes, a minimum diameter is established by taking ⅛ of the outside diameter of the tube. Where one tube sleeves over another the outside diameter of the outer tube is taken. A good practice, in many cases, is to use the next larger size of rivet than that obtained in the calculation for the minimum size.

f. Hand and machine riveting methods.—There are numerous places in the original fabrication of structures where machine riveters cannot be used and where the rivets have to be headed-up by hand. A large percentage of all repair work must also be accomplished by hand methods although mechanical riveters should be used whereever possible. In order to be able to do good work, using any of the riveting methods, considerable skill is required together with a general knowledge of riveting practices. Figure 51 shows both properly and improperly applied rivets and brings out many common faults that must be avoided.

(1) *Hand riveting.*—There are no standard types of hand riveting tools as they are manufactured to suit the particular requirements of the jobs being riveted.

(*a*) Numerous styles of hand operated squeeze riveters may be manufactured and successfully used for heading rivets not over ⅛ inch in diameter. Riveters of this type are often used in the application of the cover on aircraft using the stressed skin type of construction.



1. Correct dimensions for rivet before driving.
2. Correct dimensions for rivet after driving.
3. Correct shape for riveting tool.
4. Incorrect shape for riveting tool.
5. Result of rivet being driven on a slant.
6. Result of the use of a flat-sided rivet.
7. Result of the use of too long a rivet.
8. Result of overclinching or use of oversize rivet.
9. Damaged plate due to driving rivet at a slant.
10. Cracked rivet head due to rivet metal being too hard.

FIGURE 51.—Correct and incorrect riveting practice.

(*b*) For bucking rivets inside of round or oval shape tubular members, and straight channel sections, an expanding tool is used. Two such bucking tools are shown in figure 52.

(2) *Squeeze riveting.*—Many machine riveters in general use are of the squeeze type operated by air pressure. They are manufactured both as portable and stationary units although the portable riveter is the most satisfactory for general work. The air pressure required

to operate these riveters is between 80 and 100 pounds per square inch. Squeeze riveting is the most efficient method insofar as the strength of riveted joints is concerned. The rivet is up-set with a single operation; all rivets are headed over with uniform pressure; the heads are all formed alike; and the rivet shank is sufficiently expanded to completely fill the hole. A rivet which has been swelled or expanded all the way through the total thickness of the material insures a good bearing surface. A portable squeeze riveter is shown in figure 53. A deep throated type is the most satisfactory for general work although a shallow throated one has the greatest squeezing capacity.

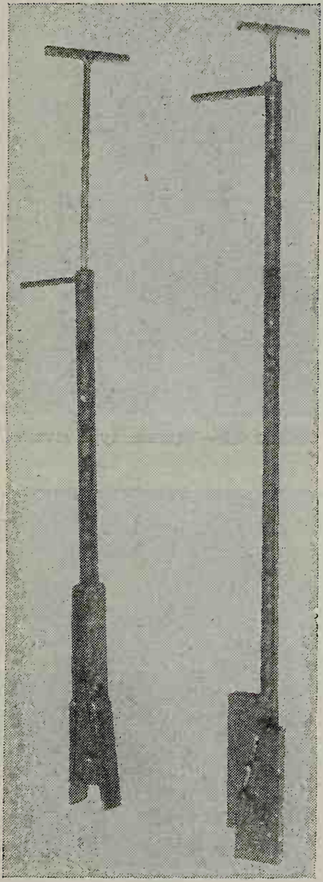


FIGURE 52.—Expanding type bucking tools.

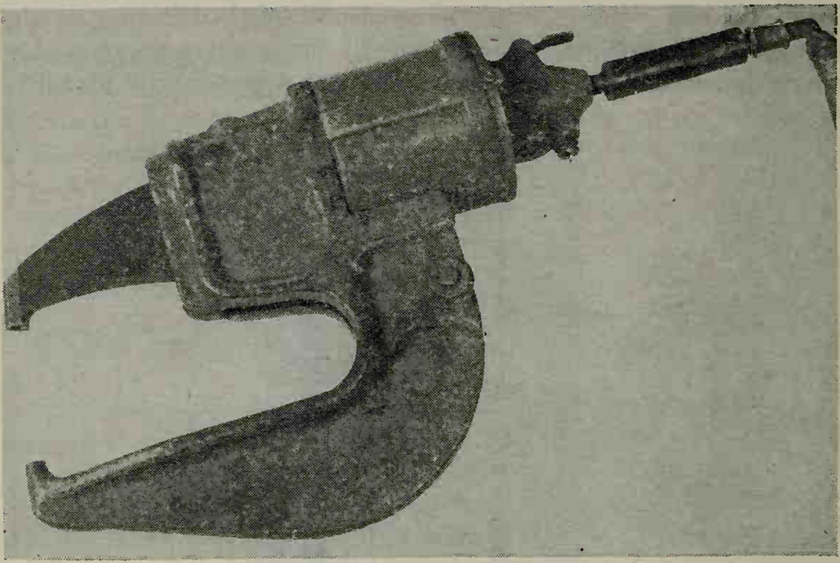


FIGURE 53.—Squeeze type riveter.

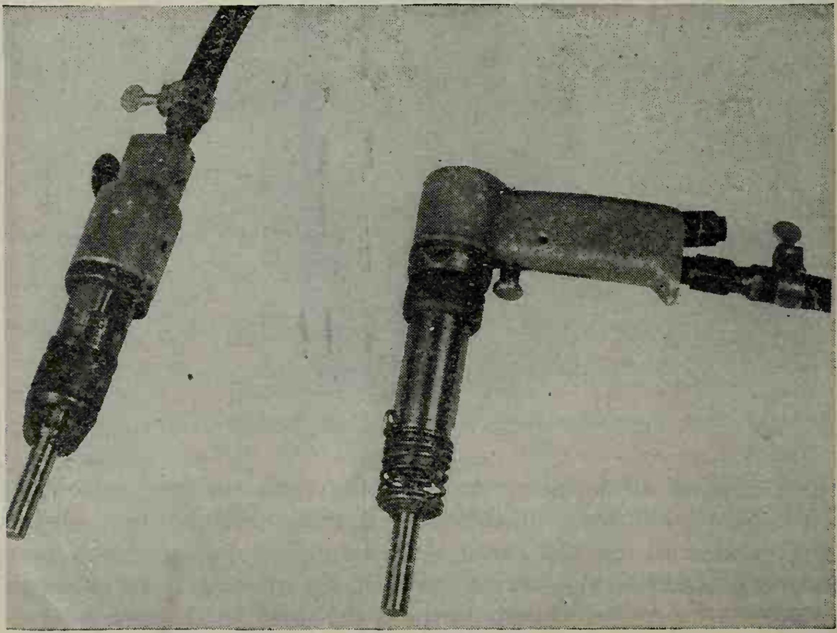


FIGURE 54.—Pneumatic riveters.

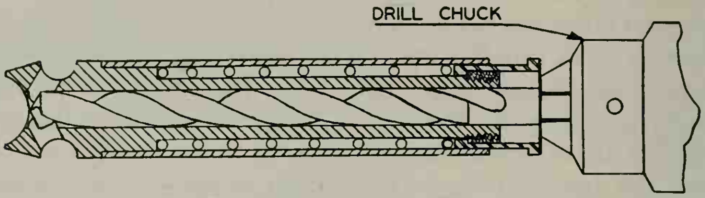
(3) *Pneumatic riveters* (fig. 54).—Assembly and repair work can often be done more efficiently with the use of the portable pneumatic riveter. As most aircraft riveting is comparatively light, and is often done in limited spaces, the riveters for this purpose should be small, light, and compact. The pneumatic riveter operates on compressed air which is supplied from a compressor or air storage tank through a hose line to the tool. When the throttle or trigger is opened, the compressed air causes a plunger in the cylinder to be blown back and forth with great rapidity and force. As the air passes through the main valve the plunger is forced down, where it strikes a rivet header, which in turn imparts the impact to the rivet. Rivet headers are supplied with different sizes of cups to make the various shaped heads. The return stroke of the piston, or plunger, is cushioned by air, reducing the jar to the operator.

(4) Most of the essentials outlined under general riveting practices should be followed in machine riveting. It is very essential that the pieces, sheets or plates, be held in close contact while being riveted. When two pieces of metal are drilled together, as is the case in most riveting work, the drill has a tendency to raise the first piece away from the lower or second piece if they are not held together tightly. This allows burs or chips to wedge between the two pieces and prevents them from being drawn close together when the rivets are headed up.

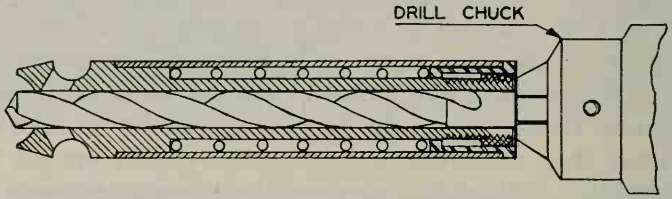
g. Removal of rivets from structures.—Rivets are removed by drilling off the heads and punching them out. They should not be cut off with a cold chisel as this will result in elongation of the hole. In order to center the drill on the rivet a guide is necessary similar to that shown in figure 55. This guide is made so that it will center the drill on the rivet head and also act as a gage for the depth of the head. The drill should be adjusted in the drill chuck as shown in figure 55① so that the point of the drill will not protrude through the guide and prevent its seating on the rivet head. This type of jig is intended to be used in an electric hand drill so that when pressure is applied the drill will protrude through the guide just enough to remove the rivet head as shown in figure 55②.

23. Types and uses of sheet-metal screws.—*a.* Hardened, self-tapping sheet-metal scews are used to a great extent in aircraft construction for the installation of cowling, fairing, etc. Screws of this type may also be employed in the joining of parts where it is impossible to buck rivets. The various types of screws manufactured by the Parker-Kalon Company are shown in figure 56, while Table X gives the size of screw and drill to be used for metal of different thicknesses.

b. As shown in figure 56, both blunt and sharp pointed screws are available. In general, the blunt end screws will be found most satisfactory, while the pointed type is used if alinement of the holes is difficult. In all screws manufactured by Parker-Kalon, the letter Z denotes the blunt or square end while A indicates the gimlet or sharp point. Screws used in aircraft construction are plated or made of stainless steel to resist corrosion.


DRILL CHUCK

① Starting position.


DRILL CHUCK

② Extended position.

FIGURE 55.—Drill guide for removing rivets.

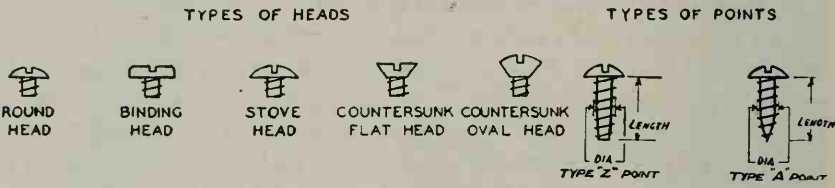

TYPES OF HEADS
TYPES OF POINTS
ROUND HEAD
BINDING HEAD
STOVE HEAD
COUNTERSUNK FLAT HEAD
COUNTERSUNK OVAL HEAD
LENGTH
DIA
TYPE "Z" POINT
LENGTH
DIA
TYPE "A" POINT

FIGURE 56.—Hardened self-tapping sheet-metal screws.

(1) Type A Parker-Kalon screws are intended for joining sheet not heavier than .050 inch.

(2) Type Z Parker-Kalon screws are used for sheets from .015 to .203 inch thick.

(3) Four point, recessed head Phillip's screws are also available in approximately the same size range as the Parker-Kalon screws. These screws require a special screw driver for each size of head, and figure 57 shows both the driver and the screw.

TABLE X.—*Specifications for the use of hardened, selftapping, sheet-metal screws*

Aluminum and aluminum-alloy sheet or tubes				Steel sheet or tubes		
Number and diameter of screw	Thickness of metal	Diameter of hole	Size of drill	Thickness of metal	Diameter of hole	Size of drill
Inches	*Inches*	*Inches*	*Number*	*Inches*	*Inches*	*Number*
No. 4 0.112	0.015	0.076	48	0.015	0.086	44
	.020	.076	48	.018	.086	44
	.025	.086	44	.025	.089	43
	.032	.086	44	.031	.093	42
	.040	.086	44	.037	.093	42
	.050	.086	44	.050	.096	41
	.058	.086	44	.062	.099	39
	.064	.089	43	.078	.101	38
No. 6 0.137	.015	.101	38	.015	.104	37
	.020	.101	38	.018	.104	37
	.025	.104	37	.025	.106	36
	.032	.104	37	.031	.106	36
	.040	.104	37	.037	.110	35
	.050	.104	37	.050	.110	35
	.058	.106	36	.062	.116	32
	.064	.106	36	.078	.120	31
No. 8 0.163	.025	.116	32	.018	.116	32
	.032	.116	32	.025	.116	32
	.040	.120	31	.031	.116	32
	.050	.128	30	.037	.116	32
	.058	.136	29	.050	.128	30
	.065	.136	29	.062	.136	29
	.082	.140	28	.078	.140	28
	.101	.147	26	.109	.149	25
	.128	.149	25	.125	.149	25
No. 10 0.186	.031	.140	28	.025	.144	27
	.040	.144	27	.031	.144	27
	.050	.144	27	.037	.144	27
	.064	.144	27	.050	.144	27
	.080	.147	26	.062	.152	24
	.101	.147	26	.078	.151	22
	.128	.154	23	.109	.161	20
	.162	.162	21	.125	.169	18

c. Hardened, selftapping drive screws, although not sheet-metal screws, may be classed with the above. These screws are used principally for plugging and sealing small drilled holes in tubular structures. Figure 58 illustrates a screw of this type, and the following table gives the specifications for their use.

TABLE XI.—*Specifications for the use of hardened drive screws*

Screw		Diameter of hole required (inches)	Number of drill
No.	Diameter (inches)		
2	0.098	0.086	44
4	.114	.104	37
6	.138	.120	31
7	.152	.136	29
8	.164	.144	27
10	.179	.161	20

(1) In steel tube structures, after the welding has been completed, each member must be treated on the inside to prevent corrosion. To do this, small holes are drilled at the highest point in each member and hot linseed oil pumped in to fill the tubes, after which holes are drilled at the lowest point and the oil drained out. These holes are all sealed after the tubes have been given the hot-oil treatment with drive screws.

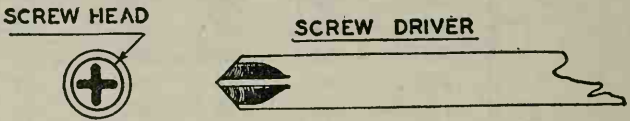


FIGURE 57.—Phillips screw and driver.

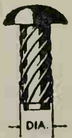


FIGURE 58.—Hardened selftapping drive screw.

(2) Drive screws may be used for other purposes such as fastening sleeves or bearings to tubular members or similar parts.

24. Spring sheet holders.—The spring sheet holder (fig. 59) consists of a small steel cylinder with a spring-actuated locking plunger. These holders are furnished in sizes from 3/32 to 3/16 inch and are used to hold seams in sheet metal during the riveting process. The different sizes are in various colors so that they may be identified easily. The pilot and locking stem are made of the correct diameter to fit the hole required by the rivet being used. Sheet holders locate the work accurately and each one forces the sheets or members together with a pressure of 50 pounds. Vibration caused by riveting will not loosen them and gaskets prevent scratching of the metal surface. Special pliers or forceps must be used to insert and remove these devices.

25. Self-locking nuts.—The self-locking nut (fig. 60) bears the trade name Elastic Stop Nut and has, in many instances, supplanted the castellated nut and cotter pin for bolted assemblies.

a. The self-locking nut is a standard nut with the height increased to incorporate a fiber collar. This added height corresponds approximately to the thickness of a lock washer.

b. The locking collar is held securely in a recess in the top of the nut. The inside diameter of the collar is smaller than that of the bolt and is not threaded. Nuts of this type are available for all standard bolts with fine or coarse threads and may be removed from the bolt and reinstalled many times without losing their locking effectiveness.

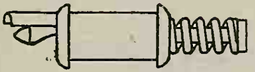


FIGURE 59.—Spring sheet-metal holder.

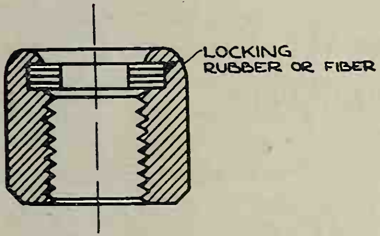


FIGURE 60.—Self-locking hexagon nut.

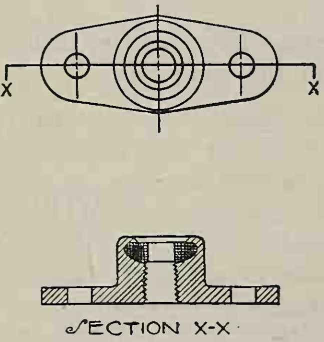


FIGURE 61.—Self-locking plate nut.

c. Aluminum-alloy aircraft nuts are furnished with anodic finish while steel nuts are cadmium plated.

d. Sawed off bolts with rough ends or bolts with cotter pin holes should not be used with this nut as the rough edges act as cutters and remove part of the fiber collar.

e. Self-locking nuts must not be used where the temperature is in excess of 250° F.

f. The plate nut (fig. 61) is a lock nut with lugs for fastening to the structure on the inside, usually by riveting. Nuts of this kind are used in assemblies where it would be impossible to prevent the ordinary type from turning.

26. Dzus fasteners (fig. 62).—Fasteners of this type are used for holding cowls, inspection covers, etc. The complete fastener consists of a grommet, spring, and stud. The stud is locked by a spring and is released by a quarter turn. The head of the stud may be oval, flat, or of the wing type.

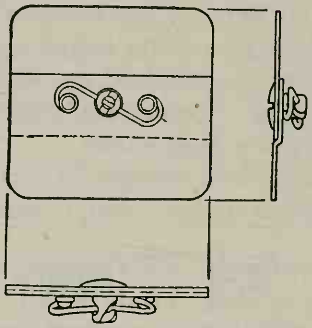


FIGURE 62.—Dzus fastener.

SECTION VI

WIRES AND CABLES

Paragraph
Aircraft cable 27
Wrapped cable terminal 28
Tuck spliced cable terminal 29
Tie rods 30
High strength steel wire 31
Turnbuckles 32

27. Aircraft cable.—*a. Nonflexible, 19 strand steel wire cable.*—This cable consists of 19 wires made of 1050, 1095, or stainless steel. Eighteen of the wires are laid around a central or core wire in two layers, having a length of lay of not more than eleven times or less than nine times the diameter of the cable. The wires are thoroughly and uniformly coated with pure tin as a protection from corrosion. This cable is used to a very limited extent on modern aircraft, having been largely replaced by round, square, or streamline tie rods. Terminals are wrapped and soldered as described in paragraph 28. Table XII gives the weight and strength of the various sizes of this cable.

TABLE XII.—*Weight, size, and strength of 19 strand cable*

Diameter (inches)	Approximate weight (pounds per 100 feet)	Breaking strength (pounds)
0. 312 (5/16)	20. 65	12, 500
0. 250 (1/4)	13. 50	8, 000
0. 218 (7/32)	10. 00	6, 100
0. 187 (3/16)	7. 70	4, 600
0. 156 (5/32)	5. 50	3, 200
0. 125 (1/8)	3. 50	2, 100
0. 109 (7/64)	2. 60	1, 600
0. 094 (3/32)	1. 75	1, 100
0. 078 (5/64)	1. 21	780
0. 062 (1/16)	0. 78	500
0. 031 (1/32)	0. 30	185

b. Flexible steel cable, 7 by 7.—This cable consists of six strands of wire laid around a similar central or core strand, with a clockwise pitch. The strands have a length of lay of not more than eight times nor less than six times the cable diameter. Each strand is composed of six wires laid around a central wire in one layer, with a counterclockwise pitch. The wires are made of 1050 to 1095 steel and are thoroughly and uniformly coated with pure tin. This cable is ordinarily used for controls, other than flight controls, such as radiator shutters, bomb releases, etc. The five-tuck Navy splice, as described in paragraph 29, is used to form terminals on this cable. Table XIII lists its weight, size, and strength specifications.

TABLE XIII.—*Weight, size, and strength of 7 by 7 flexible cable*

Diameter (inches)	Approximate weight (pounds per 100 feet)	Breaking strength (pounds)
0.312 (5/16)	16. 70	9, 200
0.250 (1/4)	10. 50	5, 800
0.218 (7/32)	8. 30	4, 600
0.187 (3/16)	5. 80	3, 200
0.156 (5/32)	4. 67	2, 600
0.125 (1/8)	2. 45	1, 350
0.094 (3/32)	1. 45	920
0.078 (5/64)	. 83	550
0.062 (1/16)	. 81	480

c. Extra flexible steel cable, 7 by 19.—This cable consists of six strands of wire laid around a similar central or core strand, with a clockwise pitch. The strands have a length of lay of not more than eight times nor less than six times the cable diameter. Each strand is composed of wires laid around a central or core wire, in two layers. The first or inner layer consists of six wires laid around the core while the second or outer layer has twelve wires laid around the six wires of the first layer. Each layer has a counterclockwise pitch and an equal length of lay. The cable is available in either carbon or stainless steel. In the carbon steel cable the wires are thoroughly and uniformly coated with pure tin as a protection from corrosion. This cable is ordinarily used for all flight controls. The five-truck Navy splice, as described in paragraph 29, is used for making all terminals.

d. Preformed wire cable, 7 by 19.—The cable is the same as that described above with the exception that the individual wires and strands composing it have been preformed into the exact helical position they take in the finished cable so that if the cable is cut or severed there is little tendency for the individual wires or strands to separate from their normal position. This preforming operation is accomplished in such a manner as to prevent twisting of the wires or strands to a harmful degree. Table XIV gives the weight, size, and strength specifications for 7 by 19 cable.

TABLE XIV.—*Weight, size, and strength of 7 by 19 extra flexible cable*

Diameter (inches)	Approximate weight (pounds per 100 feet)	Breaking strength (pounds)
½	43. 20	24, 400
7/16	34. 00	19, 000
⅜	26. 45	14, 400
11/32	22. 53	12, 500
5/16	17. 71	9, 800
9/32	14. 56	8, 000
¼	12. 00	7, 000
7/32	9. 50	5, 600
3/16	6. 47	4, 200
5/32	4. 44	2, 800
⅛	2. 88	2, 000

28. Wrapped cable terminal (fig. 63).—*a.* This splice is for use on nonflexible, 19 strand cable, and may also be applied to the flexible cables 1/16 inch and less in diameter. The materials used for making this terminal are—

(1) Grade A soft solder.
(2) Soft annealed steel wire, thoroughly tinned.
(3) Stearic acid or a mixture of stearic acid and rosin for the flux.

b. The general procedure for the splicing operation is as follows:

(1) Cut the cable to length. This must be done by mechanical means only, as the use of an acetylene torch is prohibited.

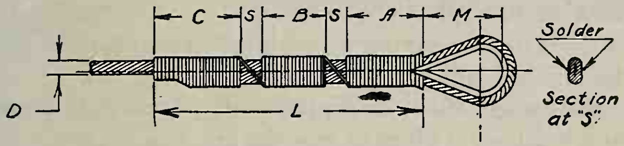


FIGURE 63.—Wrapped and soldered cable terminal.

(2) Clean the terminal thoroughly and apply a coat of flux; then loop cable over a suitable thimble and hold it in place with a clamp.

(3) Apply the wrapping wire under constant tension and according to the dimensions given in Table XV.

(4) Solder the terminal by dipping in hot solder until all spaces and inspection gaps are entirely filled even with the wrapping wire.

(5) Wipe splice with a rag to produce a smooth finish.

(6) Never use files or abrasive wheels for smoothing the solder.

TABLE XV.—*Wrapped and soldered cable terminals* [1]

D	L	A	B	C	S	M	Part No.	Wrapping wire	
								Diameter wire	Length
(All dimensions in inches)									
1/16	1 7/8	5/8	1/2	1/2	1/8	3/4	AN100–3	0. 020	25
3/32	2 1/4	3/4	5/8	5/8	1/8	3/4	AN100–3	0. 020	37
1/8	2 3/4	1	3/4	3/4	1/8	3/4	AN100–4	0. 025	58
5/32	3 3/8	1 1/8	1	1	1/8	7/8	AN100–5	0. 025	82
3/16	3 5/8	1 1/4	1	1	3/16	1 1/8	AN100–6	0. 035	109
1/4	4 1/2	1 1/2	1 1/4	1 1/4	1/4	1 1/2	AN100–8	0. 035	159

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[1] Dimensions are shown in figure 63.

c. Soldered terminals for stainless steel cable are made in the same manner with the exception of the flux used. A suitable flux for this purpose consists of a mixture of ½ pound of zinc chloride, 1 quart of water, and ⅓ fluid ounce (10 cc.) of hydrochloric acid. When the terminal is completed the flux must be neutralized in a solution consisting of 5 percent sodium carbonate (soda ash) and one percent potassium dichromate, followed by a thorough washing in clean water.

29. Tuck spliced cable terminal.—*a.* The tuck spliced cable terminal (figs. 63 and 64) is designed to be applied to 7 by 7 flexible cable and a 7 by 19 extra flexible cable. The full five-tuck Navy splice described below is used exclusively. The tools and materials used for making this splice are as follows:

(1) A 6-cord thread having a breaking strength of 32 pounds, for serving the finished splice.

(2) A small wood, fiber, or copper mallet for use in pounding the splice, and a hard wood block to serve as an anvil.

(3) A marlin spike and suitable clamp to hold the cable.

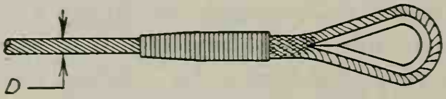


FIGURE 64.—Spliced cable terminal.

b. The following instructions are in the form of a step-by-step procedure for making the splice and refer to figure 65 which schematically illustrates the operation:

(1) Turn back points of thimble approximately 45°.

(2) Form cable around thimble and clamp in place with cable splicing vice, or wrap with wrapping cord. Leave 6 to 8 inches of cable free for splicing; this will be referred to as the "free" or "short" end to identify it from the "long" end. Right and left side of loop is determined with the cable in position for splicing, that is, long end held in a bench vice, loop in left hand, with the free end above the long end.

(3) Number 1 strand is selected nearest the thimble point on the right and unlayed from short end. Tuck under three strands of the long end. This tuck is straight through the cable going to the right of the core and may be considered as being made from left to right.

(4) Since the strands are numbered consecutively in counterclockwise direction, number 2 strand is just above number 1. Tuck number 2 in with number 1, under two strands from left to right.

(5) Tuck number 3 in with numbers 1 and 2, under one strand from left to right.

(6) Tuck core strand, the same as number 2, but bring it out below number 2. Tie core strand to long end for identification.

(7) Tuck number 6 in with the above strands (numbers 1, 2, 3, and core), passing under two strands from right to left.

(8) Tuck number 5 in where number 6 comes out, going around one strand from left to right.

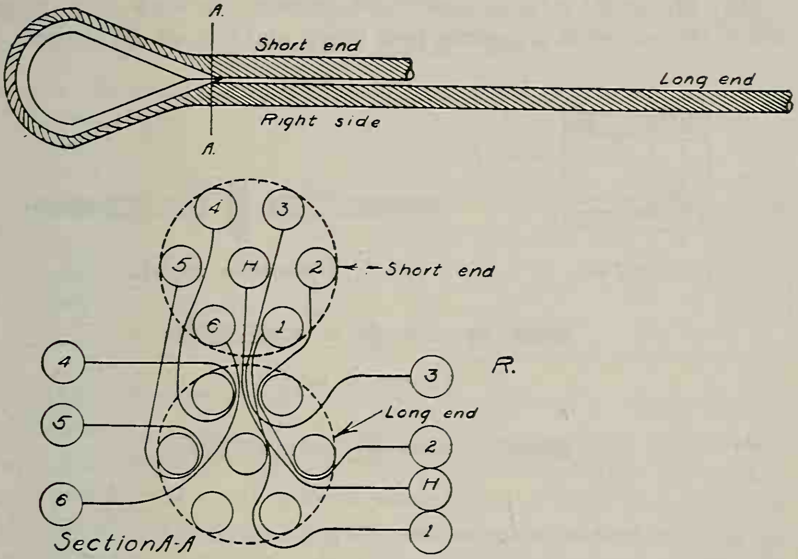


FIGURE 65.—Schematic diagram of first tuck of spliced cable terminal.

(9) Tuck number 4 in where number 5 comes out, going around one strand from left to right, coming out where numbers 1, 2, 3, 6, and core go in.

(10) Pull all strands tight and beat down snug, completing the first round of tucks. There will now be one strand emerging from each space between the strands of the long end except where the core comes out with the number 2 strand.

(11) Begin second round of tucks by tucking the first strand to the right of the core strand, going over one and under one toward the left. This binds the core strand to the center of the cable.

(12) Take each strand consecutively to the left and tuck over one and under one. The last strand tucked should come out in the same space as the core and below it.

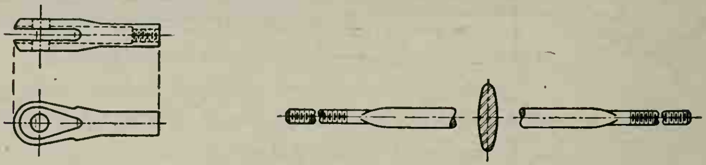
(13) Pull all strands tight and beat down, completing the second round.

(14) Proceed with a third round of tucks in the same manner as described for the second round and finish by beating the strands down.

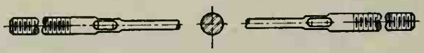
(15) Separate each strand in half and tuck one-half of each strand in the same manner as described for the second and third rounds.

(16) Cut off the six remaining untucked half strands as well as the core strand and beat down snug, completing the fourth tuck.

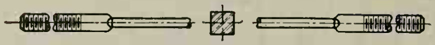
(17) Halve all strands again and proceed the same as in step 16. When the round is complete, beat down and cut off all strands.



① Tie rod end. ② Streamline tie rod.



③ Round tie rod.



④ Square tie rod.

Figure 66.—Tie rods and clevis end.

(18) Flatten the thimble points to the splice and finish by serving with cord, wrapping from ¼ inch beyond the fifth tuck to a point midway between the second and third tucks. The ends of the cord are each inserted under four wraps and pulled up tight.

(19) Complete the splice by giving it two coats of orange shellac.

30. Tie rods.—Tie rods are used for bracing the various rigid structural units of certain types of airplanes, having replaced practically all cables for this purpose. They are made of either cadmium-plated medium carbon-steel or nickel-chromium steel, which require no protective coating. Tie rods are made in three types—round, square, and streamline. The round and square rods are used principally for internal bracing while the streamline type is generally employed for all external applications. Tie rods may be obtained in any length and are supplied with threaded ends, one right hand and the other left. Clevices are screwed onto these ends to form terminals, and adjustment in length is made by rotating the tie rod to the right or left. The final setting is maintained by a lock nut. The three types of tie rods, as well as a set of tie rod ends, are shown in figure 66. The following table gives the size, range, and strength for tie rods, and applies to all three types.

TABLE XVI.—*Aircraft tie rods*

Size and threads (per inch)	Ultimate strength (pounds)
6-40	1, 000
10-32	2, 100
¼-28	3, 400
5/16-24	6, 100
⅜-24	8, 000
7/16-20	11, 500
½-20	15, 500
9/16-18 (streamline only)	20, 200
⅝-18 (streamline only)	24, 700

31. High strength steel wire.—This material has been used in some instances for internal bracing of fuselages, wings, and control surfaces, but has largely been replaced with tie rods. It is also used to some extent for cowl and cover fastening pins. High strength steel wire is manufactured from plain carbon steel and is coated with tin for protection against corrosion. It is procurable in sizes from 0.032 inch to 0.306 inch. The ultimate strength ranges from 225 pounds in the smallest size to 14,000 pounds in the maximum diameter.

32. Turnbuckles.—Turnbuckles are used almost universally as a means of adjustment for the tension of wires and cables. The assembly is composed of three parts—the barrel and two shanks—which vary in size, depending upon the cable for which they are to be used. There are three standard types of turnbuckles in general use which accomodate the various terminals and connection. These types are the cable eye and fork, the cable eye and pin eye, and the double cable eye. Naval-brass alloy is used in the manufacture of turnbuckle barrels while all shanks are made of steel. The entire assembly is coated with cadmium to prevent corrosion. Table XVII lists the standard turnbuckle sizes with their corresponding strengths.

TABLE XVII.—*Turnbuckles*

Size and thread	Strength (pounds)
6–40	800
10–32	1, 600
12–28	2, 100
¼–28	3, 200
5⁄16–24	4, 600
⅜–24	6, 100

SECTION VII

BUMPING AND FORMING METHODS

Paragraph
General 33
Hand bumping and hand bumping tools 34
Power bumping and pressing 35
Metals which may be formed by bumping 36
Bending aluminum alloy 37

33. General.—The manufacture of small airplane parts is accomplished by the use of the bar folder, cornice brake, metal spinning lathe, bumping hammer, and various hand tools. Regardless of the method used, special care must be taken to prevent scratches on aluminum and aluminum alloys. Scribers should not be used for marking lines as every scratch induces fatigue failure. A pencil will be found to be satisfactory for lay-out work but must be kept sharp to insure accuracy. Bench tops should be kept clean and free from chips, filings, etc., and should be made of material hard enough that chips and other foreign materials will not become imbedded in them. Vise jaws must be smooth and covered with a soft metal for further protection.

34. Hand bumping and hand bumping tools.—*a.* Hand bumping is a process of forming sheet metal into complex curvatures and shapes. Bumping differs from raising in that the metal is usually forced downward in a curved surface, while in raising, the metal is forced upward in a straight line. Bumping may be done either by hand or power equipment, or by a combination of the two.

b. In hand bumping the metal is formed to shape, either in dies or on sand bags, by the application of a number of light blows with a mallet or special bumping hammer.

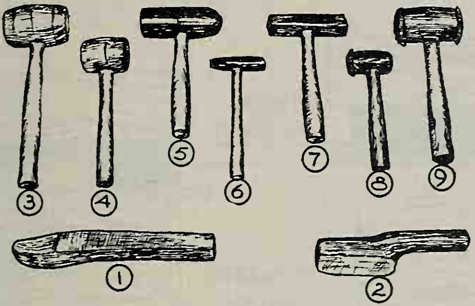
c. Bumping tools (fig. 67) are made of various materials.

(1) Hammers may be made of metal, wood, rubber, rawhide, bakelite pyralin, etc., in a variety of sizes and shapes.

(2) Mallets are made of rawhide, hickory, or maple. The face of the mallet, as well as the other bumping tools, should be kept smooth and free from dents to prevent marring the work.

(3) Sandbags for bumping are made of rawhide or paraffin-coated canvas.

d. Dies for hand bumping may be made from various materials. As a rule, female dies are used; however, male dies are more suitable for some operations. When making wood dies, any hard wood may be used although maple is the most satisfactory. The wood is usually cut in planks 2 inches thick and glued together to the desired size. The form is then cut to shape with saws; gouges, wood chisels, and rasps, after which it is smoothed with sandpaper and given several coats of shellac. Unless shellacked soon after cutting, the wood form will check and crack. The form should be smoothed with sandpaper after each coat of shellac has dried.



1 and 2. Maple flanging mallets.
3, 4, 5. Maple mallet with one rounded end.
6 and 7. Small and large pyraline or celluloid hammers.
8 and 9. Rawhide mallets.

FIGURE 67.—Bumping tools.

35. Power bumping and pressing.—*a.* Power bumping is done by means of a power hammer. Molds or forms may be employed although their use requires especially skilled workmen. The metal should be smoothed with the power hammer by a number of light blows rather than a few heavy blows to prevent the metal from buckling and cracking. The metal should be lubricated with a light oil on both sides to prevent galling, and the surface of the hammer and anvil must be perfectly smooth.

b. Most aircraft factories use hydraulic presses for production work. The parts are formed by using mating male and female wood or metal dies, or by using a male die only, with a heavy rubber pad or blanket on the platen of the machine (fig. 68). When using this method, large spaces on the platen must be filled with fiber, wood, or other materials, to insure sufficient pressure where needed. Where the draws are shallow, the rubber pad is satisfactory, while for deep draws, the mated dies will be found necessary.

c. The drop hammer is used where many duplicate parts are to be made and works in the same manner as a pile driver. The hammer is raised by tightening a large rope wound around a revolving drum and the hammer blow is delivered by allowing the rope to slack.

d. Forms for power bumping and pressing.—In the production of forms for power bumping and pressing a plaster mold is made of the part to be formed in the die. Lead, zinc, or other alloyed metals are then melted and cast around this plaster mold. The female die is usually made first and when cool, a metal of a lower melting point is cast in the female die to form the male member. These dies are bolted or keyed to the anvil or hammer so as to mate perfectly when in use.

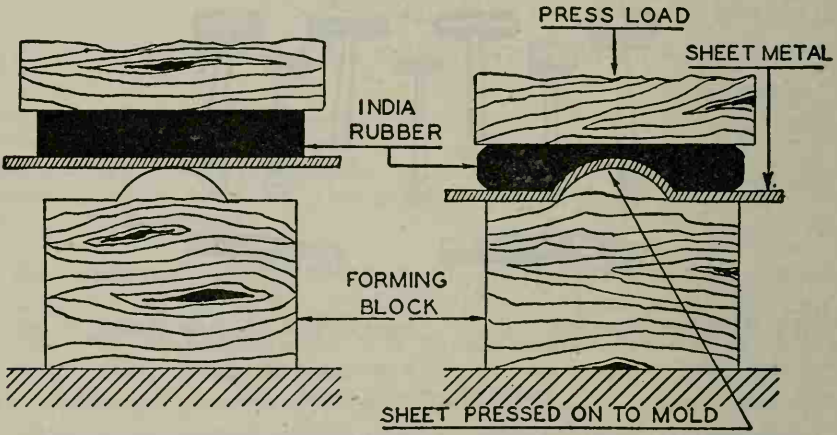


FIGURE 68.—Forming sheet metal by means of male die and heavy rubber blanket.

36. Metals which may be formed by bumping.—Bumping may be successfully used for forming several metals employed in aircraft construction. Forms may be worked either from the plain sheet or from sections welded together.

a. Alloys 2S and 3S are used extensively for forming cowling, fairing, fuel tanks, and other nonstructural members, and should be annealed before bumping. If deep draws are to be made, the material must be reannealed several times during the operation.

(1) Alloy 24S is used for forming structural members. Because of its work hardening characteristics frequent annealing is required.

(2) Alloy 52S may be used in a like manner. It does not require heat treatment after bumping but is not as strong as the 24S material.

b. Both Inconel and stainless steel are used to a considerable extent in assemblies where bumping and drawing are required.

(1) Stainless steel must be annealed before any forming of this type may be done. Sheets, as they are received from the mill, are in the annealed state and are ready to be worked. Subsequent annealing, however, is required as excessive bumping, rolling, etc., work hardens the material.

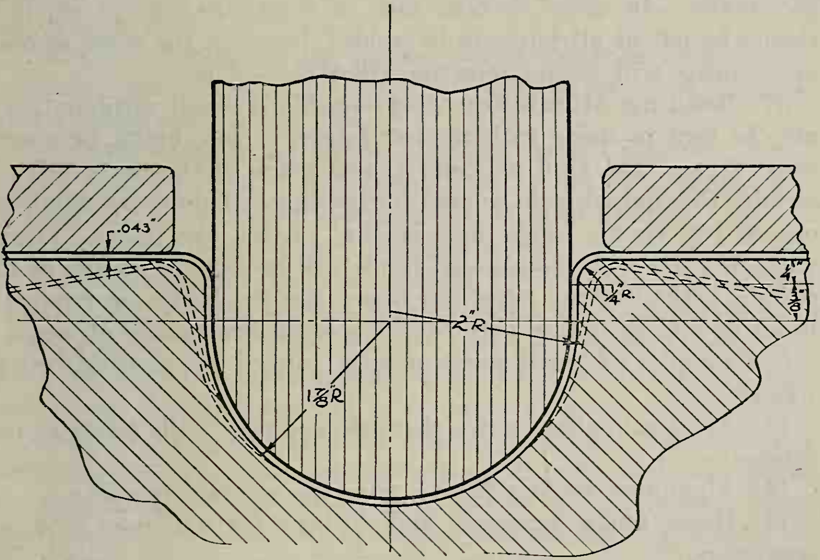


FIGURE 69.—Stamping dies for nickel-iron alloy, showing allowance for spring-out.

(*a*) Sheet stock .064 inch or less should be heated to between 1,900° F. and 2,100° F., then quenched in air and all scale removed.

(*b*) Sheet stock thicker than .064 inch should be heated in the same way but quenched in cold water.

(2) Inconel must also be annealed before working. The material may be formed with considerable ease and a minimum of "spring out" if worked shortly after this annealing process. It has been found that the metal will still have a slight "spring out" which may be compensated for when the forming dies are being built. This "spring out" will be approximately $\frac{1}{16}$ inch per 1 inch of diameter.

For example, to form a stack 4 inches in diameter would require a die of the proportions shown in figure 69.

(*a*) Annealing is accomplished by heating the material in a closed oven for approximately 20 minutes at 1,800° F. After this period it should be removed from the furnace and allowed to air cool. Inconel should not be quenched in water or oil.

(*b*) Stamping or bumping of the sheet stock should be completed in one operation. Repeated bumping blows will have no effect unless the material is reannealed after each forming operation. Repeated annealing increases scaling thus rendering the material less suitable for service. In order to take care of shrinkage, $1/64$ to $1/32$ inch should be left at all joints to be welded, however, the exact amount of shrinkage will depend upon the skill of the welder.

37. Bending aluminum alloy.—*a*. Many small airplane parts may be bent to shape with the bar folder, cornice brake, or over a wood form. The kind of material and shape of the parts will determine the equipment to be used for bending. Thin parts, requiring one or two simple bends, may be bent on the bar folder. Heavy parts or parts with complicated bends will necessitate the use of the cornice brake. Other parts too heavy for the brake, or requiring bends of a large radius, may require special forms made of wood.

b. Examples of small parts, usually formed by bending, are as follows:

(1) Aluminum-alloy angles, channels, and practically all structural fittings.

(2) Aluminum cowling, fairing, wing tip, and tank repairs.

(3) Brass tanks, brackets, and fittings for radiators and oil separators.

(4) Stainless steel parts for exhaust stacks, smoke screen, tanks, and cockpit inclosures.

SECTION VIII

REPAIRS

	Paragraph
General	38
Open section members	39
Stressed skin covers	40
Waterproof skin seams	41
Metal floats	42
Corrosion-resistant steel parts	43

38. General.—Monocoque and semimonocoque construction is used in a large percentage of the modern high performance airplanes.

In either of these types of structures the skin or thin sheet covering is stressed to carry high loads.

a. Full monocoque construction is the term applied to a structure in which the entire loading is transmitted through the skin. No longitudinal members are employed, although bulkheads are spaced at intervals throughout the unit to give rigidity and maintain the proper contour. These bulkheads may be built-up aluminum-alloy channels, U-sections, or slotted tubing, held in place by rivets.

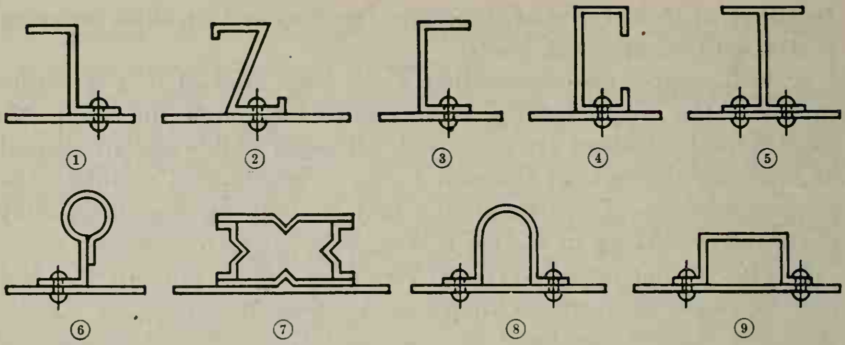
b. The semimonocoque type of structure differs only in the fact that longitudinal members known as stringers are employed. These stringers connect the bulkheads and aid the skin in transmitting the stresses.

c. Repairs to either of the above types of structures must be very carefully made in order that the highly stressed parts may continue to carry their share of the load.

39. Open section members.—*a.* Open section members such as angles, channels, tees, and I-beams, used as ties or columns, must be replaced, if possible, by new members when badly bent, fractured, cracked, or crinkled. Long members which are continuous over several riveted joints may be repaired by inserting new parts of equal or larger cross section, from joint to joint, lapped into the joints, and fastened with the rivets which are a part of these joints. No splice should be made outside of the joints in the original structure unless the reinforcement is extended over the entire distance between the joints and fastened directly to them. This reinforcement may then be riveted at intervals to the member being spliced, but must have a net area (total area less area cut out by rivet holes), at all sections, equal to that of the original member. The cross section of the repair member should be similar to that of the original.

b. Longitudinal members or stringers in semimonocoque fuselages may be one of the types shown in figure 70. These members are riveted to the skin of the structure for more rigid construction, and in some cases longitudinal stiffeners are formed in one edge of the covering itself as shown in figure 71.

(1) Damaged sections of stringers should be cut out and replaced by new sections as shown in figures 72 and 73. In the case of extruded stringers, where no replacement stock is available, a section may be formed out of aluminum-alloy sheet stock, provided the formed stringer is dimensionally similar to the extruded section and has at least the same area. To simulate the bulb on bulb-angle sections when bulb-angle stock is not available a stiffening flange should be formed on the splice piece.



1. Z-section.
2. Balanced Z-section.
3. Channel section.
4. C-section.
5. I-section.
6. Bulb angle.
7. Air corps section for stainless steel spot welded.
8. U-section.
9. Hat section.

FIGURE 70.—Typical stringer sections.

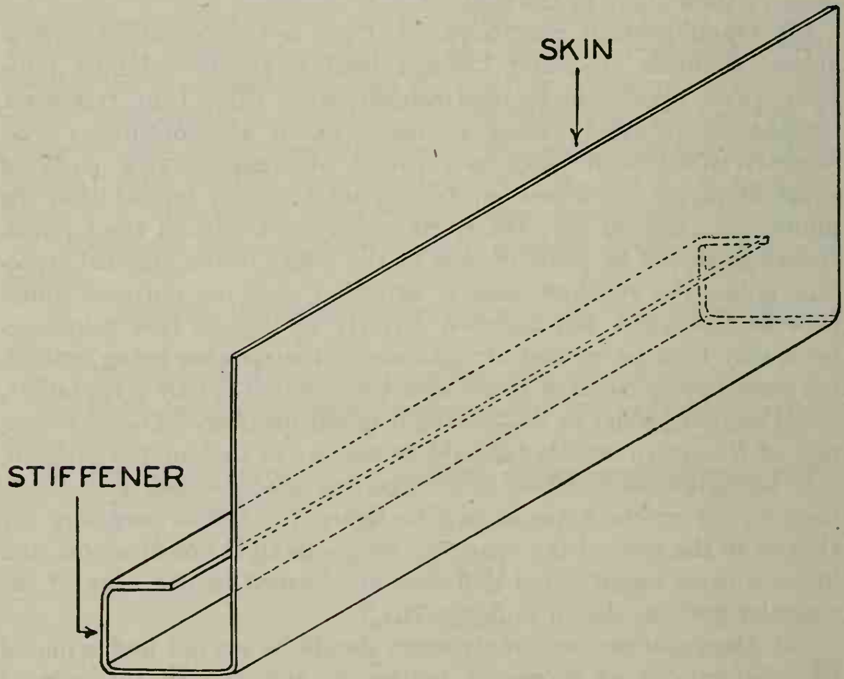


FIGURE 71.—Stiffener formed in stressed skin cover.

(2) When possible, wing stringer splices should be located between bulkheads to eliminate the possibility of interference where the stringer passes through bulkhead cut-outs. Where rivets have deformed a stringer clip the clip should be cut off and a new clip riveted to the bulkhead and stringer.

(3) General repair practices on fuselage stringers is similar to that employed for wing structures. The length of the repair splice and number of rivets should be equal to that of a similar splice plate in the original member. The repair splice should extend at least twice the width of the member on each side of the break. The minimum distance from the center of the rivet hole to the end of the piece should be not less than two diameters of the rivet in all cases.

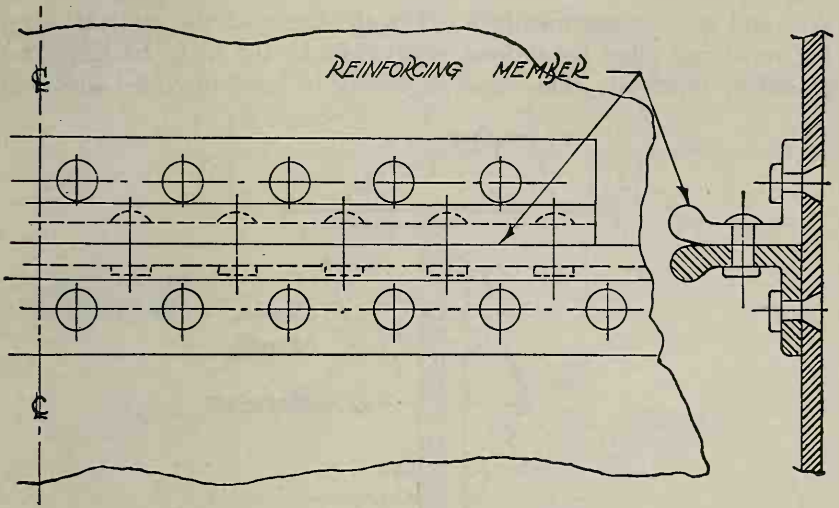


FIGURE 72.—Bulb angle stringer splice.

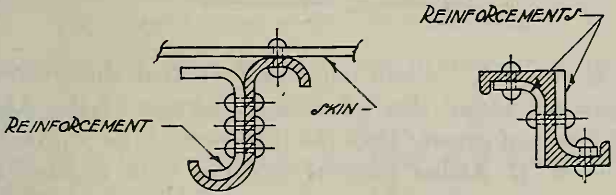


FIGURE 73.—Zee extrusion splices.

(4) The correct method for repairing an open section channel member is shown in figure 74. Where the structural members are of the slotted tubular type, damaged units should be replaced with new ones. Wherever this is not practical tubular sections for splicing may be formed around a filler, and the slotted openings milled before removing this filler.

c. Bulkhead repairs.—Where fuselage bulkheads are originally spliced on the horizontal centerline, damaged sections may be replaced. In case it is desired to splice in a replacement for only a portion of a bulkhead, the splices for this new section should be the same as the splice joining the original halves. Serious damage to bulkheads should be of rare occurrence and then will probably be impractical to repair. Bent or broken parts may be straightened and reinforced by riveting plates or angles on each side of the damaged section, in cases where a repair must be made.

40. Stressed skin covers.—*a.* Damage to a stressed skin cover is generally due to a hole or tear in the skin or a buckling of the skin and reinforcing members. The thickness of the material used for repairing must be at least equivalent to the material being replaced or repaired. The same gage may be used provided identical material is available. Plain, anodically-treated sheet should be repaired with an Alclad sheet, but the thickness of the Alclad sheet must be 10 percent greater than the thickness of the original material. Number 17 or 17 Alclad may be replaced with number 24 Alclad without any increase in thickness.

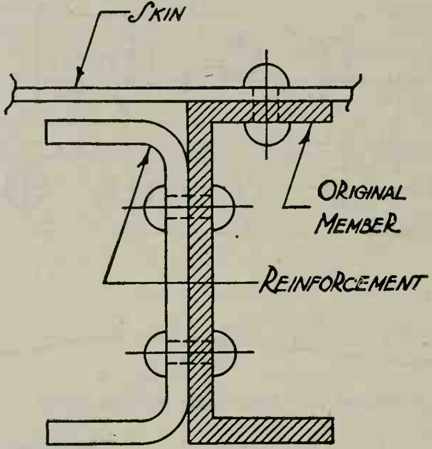


FIGURE 74.—Channel section splice.

b. The following methods and calculations illustrate general principles that may be used in the repair of all stressed skin units:

(1) *Repair of corrugated skin covers.*—In the repair of breaks in all types of corrugations, the sheets are assumed to be subjected to a stress equal to the crippling stress. This is used to determine the size of the reinforcing plate and the number of attaching rivets required, the values for which are given in Table XVIII. A specific example is outlined below to show the method of repairing a break in a corrugated section of stressed skin and figure 75 shows this type of repair.

(*a*) Assume 0.051 inch gage corrugates skin stressed to 40,000 pounds per square inch.

(*b*) Reinforcement should be at least the gage of the corrugation or preferably one gage heavier.

(*c*) Cross section area removed=developed length of break by thickness of metal=.155 square inch.

(*d*) Load in reinforcement=.155 by 40,000=6,200 pounds.

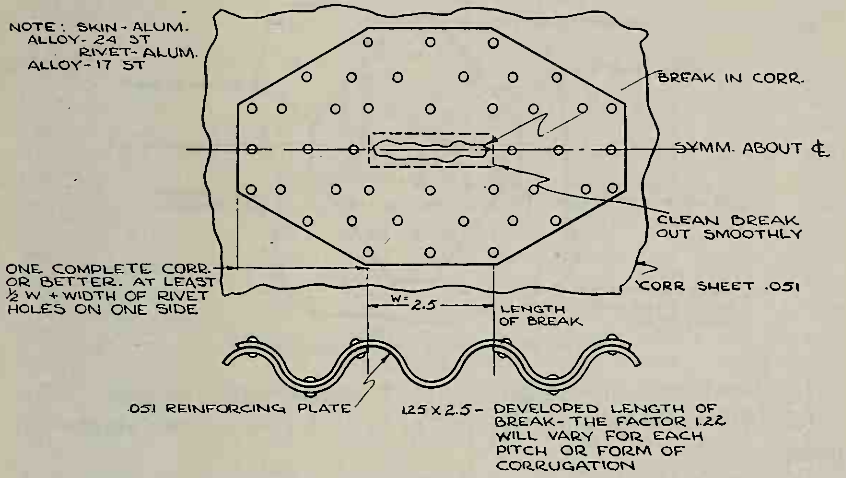

NOTE: SKIN-ALUM. ALLOY-24 ST
RIVET-ALUM. ALLOY-17 ST
BREAK IN CORR.
SYMM. ABOUT ℄
CLEAN BREAK OUT SMOOTHLY
CORR SHEET .051
ONE COMPLETE CORR. OR BETTER. AT LEAST ½ W + WIDTH OF RIVET HOLES ON ONE SIDE
W=2.5
LENGTH OF BREAK
.051 REINFORCING PLATE
1.25 X 2.5 - DEVELOPED LENGTH OF BREAK - THE FACTOR 1.22 WILL VARY FOR EACH PITCH OR FORM OF CORRUGATION

FIGURE 75.—Corrugated stressed skin patch.

(*e*) Allowable bearing strength of ⅛-inch rivet on .051 sheet=477 pounds.

(*f*) Allowable shear strength of ⅛-inch rivet=369 pounds.

(*g*) Number of rivets required$=\frac{6,200}{369}=17$. (Note that the shear strength, which is lower than bearing strength is used to obtain required number of rivets.)

(*h*) A minimum of 17 rivets should be used in front and behind the break to reinforce the corrugation.

(2) *Repair of smooth skin covers.*—In smooth skin structures the maximum allowable tension stress is considered to be 43,600 pounds per square inch and this figure accounts for reduction in area due to rivet holes. Reinforcement plates for repairs should always be at least one gage heavier than the damaged skin. As the size of break increases, this difference in gage should increase accordingly. The ragged edges of a hole should be cut away so that there are no sharp corners. This type of repair applies only to smooth skin that carries

stress and does not apply to top skin on corrugations, cowling, fairings, etc. A specific example of smooth skin reinforcement is given below and is shown in figure 76.

(*a*) Assume skin gage=.028 inch stressed to 43,600 pounds per square inch.

(*b*) Cross section area removed=.028 by 2.5=.07 square inch.

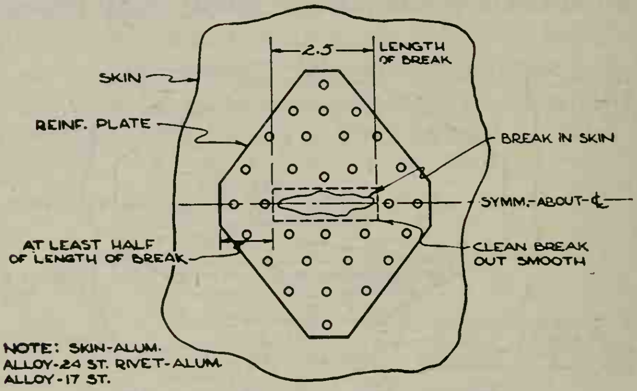

2.5
LENGTH OF BREAK
SKIN
REINF. PLATE
BREAK IN SKIN
SYMM.-ABOUT-℄
AT LEAST HALF OF LENGTH OF BREAK
CLEAN BREAK OUT SMOOTH
NOTE: SKIN-ALUM. ALLOY-24 ST. RIVET-ALUM. ALLOY-17 ST.

FIGURE 76.—Smooth stressed skin patch.

(*c*) Load in reinforcement=.07 by 43,600=3,050 pounds.

(*d*) Allowable bearing strength of ⅛-inch rivet on .028 sheet=237 pounds.

(*e*) Allowable shear strength of ⅛-inch rivet=369 pounds.

(*f*) Number of rivets required=$\frac{3,050}{237}$=13.

(*g*) A minimum of 13 rivets should be used in front and behind break to attach reinforcement to skin.

TABLE XVIII.—*Shear and bearing strengths of aluminum-alloy rivets and sheet*

Allowable single shear strength of aluminum-alloy rivets.

Composition of rivet (alloy)	Ultimate strength of rivet metal (pounds per square inch)	Diameter of rivet (inches)							
		1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
		Allowable single shear strength (pounds per square inch)							
A17ST	25,000	76	172	306	479	690	1,227	1,917	2,761
17ST	30,000	92	206	368	573	828	1,472	2,300	3,313
24ST	35,000	107	241	429	670	966	1,718	2,684	3,865

TABLE XVIII.—*Shear and bearing strengths of aluminum-alloy rivets and sheet*—Continued

Allowable bearing strength of 24ST aluminum-alloy sheet

Thickness of sheet (inches)	Diameter of rivet (inches)							
	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
	Bearing strength of sheet (pounds per square inch)							
0.014	78	118	157	196	236	315	393	472
.016	90	135	180	225	270	360	450	540
.018	101	151	202	253	303	405	506	607
.020	112	168	225	281	337	450	562	675
.025	140	210	281	351	421	562	703	843
.032	180	269	360	449	540	720	900	1, 080
.036	202	303	405	506	607	810	1, 012	1, 215
.040	225	337	450	562	675	900	1, 125	1, 350
.045	253	379	506	632	759	1, 012	1, 265	1, 518
.051	286	430	573	716	860	1, 147	1, 434	1, 721
.064	360	539	720	899	1, 080	1, 440	1, 800	2, 160
.072	405	607	810	1, 012	1, 215	1, 620	2, 025	2, 430
.081	455	683	910	1, 138	1, 366	1, 822	2, 278	2, 733
.091	511	767	1, 023	1, 279	1, 535	2, 047	2, 559	3, 071
.102	573	860	1, 147	1, 434	1, 721	2, 295	2, 868	3, 442
.128	720	1, 079	1, 440	1, 799	2, 160	2, 880	3, 600	4, 320

Allowable bearing strength of 24ST Alclad aluminum-alloy sheet

0.014	71	107	143	179	215	287	358	430
.016	82	123	164	204	246	328	410	492
.018	92	138	184	230	276	369	461	553
.020	102	153	205	256	307	410	512	615
.025	128	192	256	320	384	512	640	768
.032	164	245	328	409	492	656	820	984
.036	184	276	369	461	553	738	922	1, 107
.040	205	307	410	512	615	820	1, 025	1, 230
.045	230	345	461	576	691	922	1, 153	1, 383
.051	261	391	522	653	784	1, 045	1, 306	1, 568
.064	328	491	656	819	984	1, 312	1, 640	1, 968
.072	369	553	738	922	1, 107	1, 476	1, 845	2, 214
.081	415	622	830	1, 037	1, 245	1, 660	2, 075	2, 490
.091	466	699	932	1, 165	1, 399	1, 865	2, 331	2, 798
.102	522	783	1, 045	1, 306	1, 568	2, 091	2, 613	3, 136
.128	656	983	1, 312	1, 639	1, 968	2, 624	3, 280	3, 936

(3) On wing skins where flush type rivets are used to present a smooth surface to the air flow it is necessary to use flush type access doors and patches. To correspond in appearance, repairs should be made on the bottom surface where possible. The reinforcement plate should be of aluminum-alloy (Alclad) sheet at least one gage heavier than the original skin although the door may be of the same thickness. The reinforcement plate should extend beyond the ends of the opening approximately twice its width. There should be not less than two rows of rivets in the reinforcement and the rivets should be spaced similarly to adjacent rivets in the structure. A repair of this kind is shown in figure 77.

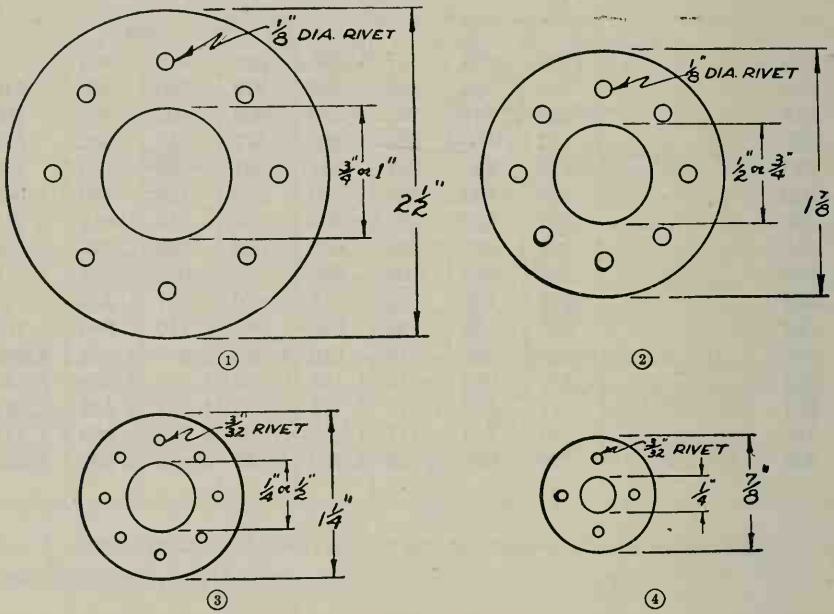


FIGURE 77.—Flush type patch with access door.

(4) *Standard reinforcement for small holes in thin sheets.*—The reinforcements shown in figure 78 are to be considered standard for round holes up to 1 inch in diameter in stressed thin sheets. Whether the reinforcement washers are single or double will depend on the nature of the stress, the amount of vibration, etc. In any case, the thickness of each washer will be at least equal to the thickness of the sheet.

(5) *Repair of trailing edge—(fabric covered surface)*.—In the case of a damaged trailing edge strip, the damage portion is cut away and

the method of repair is comparatively simple. It is usually most convenient to make the extremities of the cut centrally between trailing edge ribs. This permits the splice clips for attaching a new section to be installed more easily. Figure 79 shows a typical method of splicing ends of trailing edge strips.

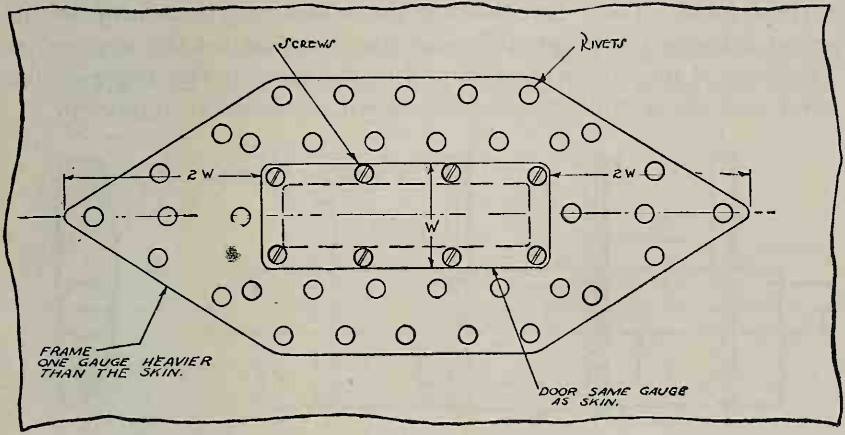

SCREWS
RIVETS
2 W
2 W
W
FRAME ONE GAUGE HEAVIER THAN THE SKIN.
DOOR SAME GAUGE AS SKIN.

FIGURE 78.—Standard reinforcements for small holes.

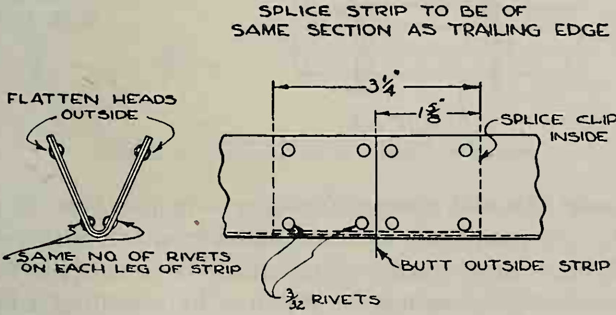

SPLICE STRIP TO BE OF SAME SECTION AS TRAILING EDGE
FLATTEN HEADS OUTSIDE
3 1/4"
1 5/8"
SPLICE CLIP INSIDE
SAME NO. OF RIVETS ON EACH LEG OF STRIP
BUTT OUTSIDE STRIP
3/32 RIVETS

FIGURE 79.—Trailing edge splice.

(6) *Repair of fuselage side skin.*—The repair of a crack in the side skin is slightly different from the repair of a hole. In this case it is not necessary to smooth the edges of the break the full length; however, it is important that a small round hole be drilled at each end of the crack. These holes will tend to prevent the crack from spreading and thus insure a better repair job. The method of finding the number of rivets and the size of the patch required is the same as outlined for smooth skin repairs.

(7) *Repair of metal nose cover on flaps.*—The repair of the metal nose cover on flaps requires the removal of all fabric adjacent to the damaged portion. The size of the cover plate prohibits the use of hand holes as an aid in attaching the repair sheet. The simplest method is to remove a complete section of the nose cover and install a new one. Lap splices should be made at a nose rib as this insures a rigid joint. Tools for bucking the attaching rivets may be inserted between the torque tube and the short side of the nose cover. The gage of the repair sheet should be the same as the original nose cover and the section should be installed as shown in figure 80.

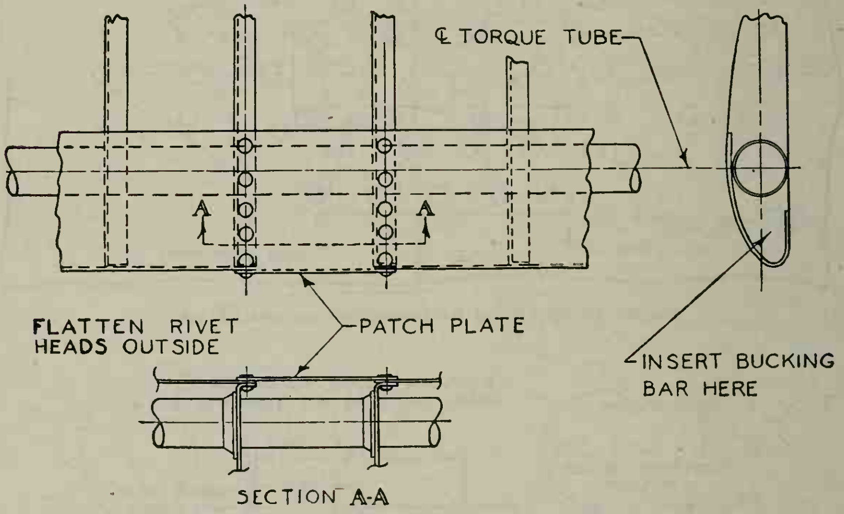


FIGURE 80.—Repair of metal nose cover on flaps.

(8) *Repair of metal covered stabilizer.*—In this type of structure all sections are completely inclosed, making any repair to the skin rather difficult. Breaks in the skin that can be cleaned out to a diameter of not over 5 inches may be repaired by installing a hand hole as shown in figure 81. The cover plate should be at least the gage of the skin, although a gage heavier is preferable. The covering plate must be screwed on, requiring the installation of elastic stop nuts or tapped holes in the reinforcing ring; the first method being the most satisfactory.

(*a*) In case the damaged section is too large to repair through hand holes, the entire panel, or a large portion of it, must be removed. If the entire panel is replaced, the new panel should be riveted to the front spar first. This permits the rear end to be raised and bucking tools introduced through the opening. To aid in riveting, a hand hole may be made on the repair plate before it is attached to the stabilizer. If only a portion of the panel is removed, the transverse splice should come at a skin stiffener. A hand hole may also be incorporated in this repair if desired. The method of attachment should be the same as that for an entire panel replacement.

(*b*) The above instructions are also applicable to repairs to the nose cover of the stabilizer.

(9) *Repair of fuselage bottom skin.*—The most important repairs of this kind are those resulting from bad landings, where the bottom skin and its supporting rings are crushed. The repair required in such cases may be outlined as follows:

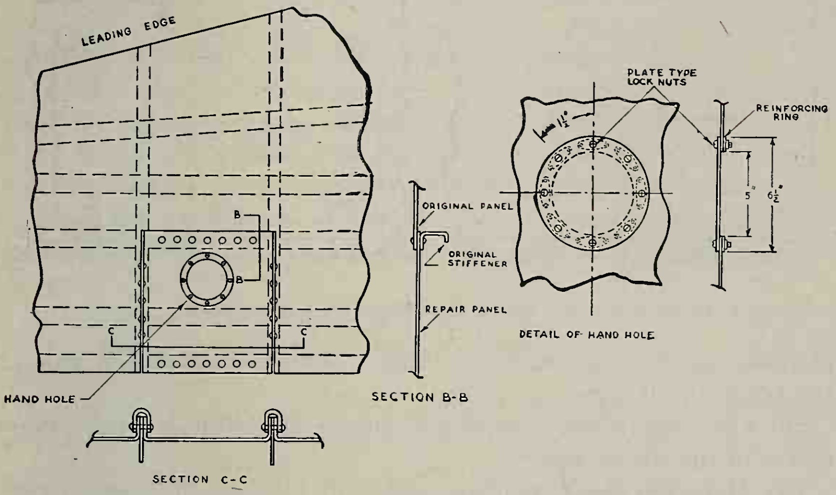

LEADING EDGE
B
B
C
C
HAND HOLE
SECTION C-C
ORIGINAL PANEL
ORIGINAL STIFFENER
REPAIR PANEL
SECTION B-B
PLATE TYPE LOCK NUTS
$1\frac{1}{2}$"
REINFORCING RING
5"
$6\frac{1}{2}$"
DETAIL OF HAND HOLE

FIGURE 81.—Repair of metal-covered stabilizer.

(*a*) Remove rivets attaching lower section to longerons and remove entire damaged area. (The extent of the section to be removed in the fore and aft direction will be governed by the transverse splices.)

(*b*) Remove all damaged lower rings up to the splice. In case it is not necessary to remove the entire lower ring, cut it well above the damaged portion and splice in a new section. This splice should be made in the same manner as the splice connecting the upper and lower sections of the original ring.

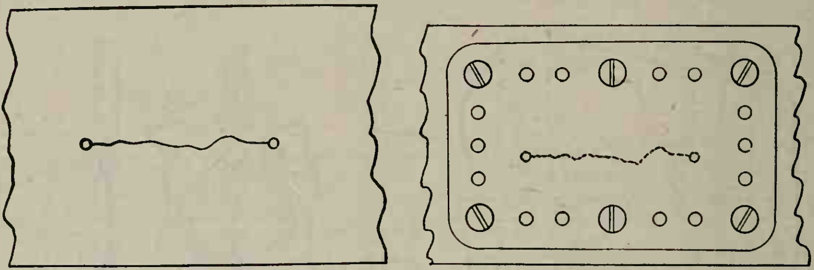
(*c*) Rivet side skin to new lower ring sections then rivet new section of bottom skin to rings.

(*d*) Make all necessary splices with the same lap, and rivet spacing as used in adjacent splices.

(10) *Repair of cracks in nonstressed parts.*—Parts, such as engine cowling, fairing, etc., are generally considered nonstressed. However, they are subject to vibration which in time will cause cracks. Figure 82 shows a method of repairing cracks in such parts and the procedure is as follows:

(*a*) Drill a small hole approximately ⅛ inch in diameter at each end of the crack. This distributes the strain over a larger area and prevents the crack from spreading.

(*b*) Cut a piece of reinforcing material of the same type and thickness as the original sheet; large enough to extend well around the crack on all sides.



① Holes drilled to prevent cracks from spreading. ② Patch held in place with screws for drilling and riveting.

FIGURE 82.—Repair of cracks in nonstressed parts.

(*c*) Form the piece to the proper shape, cut a radius on the corners, and drill the corner holes.

(*d*) Hold the patch in place, and drill through the corner holes into the cowling.

(*e*) Attach the patch temporarily with sheet metal screws, and if desirable, paint the under side of the patch before assembly.

(*f*) Lay out and drill the remainder of the holes for $\frac{3}{32}$- or ⅛-inch rivets.

(*g*) Insert and head the rivets on the same side as adjacent rivets.

41. Waterproof skin seams.—*a.* On airplanes where waterproof seams are required, a special tape is usually installed in all outer joints. A typical material for this purpose is PAW tape, the use of which is described in detail in this paragraph:

(1) The dry cement on PAW tape becomes soft immediately upon application of benzine, gasoline, kerosene, or light oil. Thus it is possible to stick down a strip of the material by moistening one side of the tape only and pressing it into place. The tape can be left in this position for an indefinite period without injurious effect.

(2) When the joint is to be completed, the other surface can be

moistened and the assembly made in the usual manner. If the joint is not permanently assembled within 48 hours, the cement can be resoftened by brushing kerosene on the tape just before riveting.

(3) As soon as the joint is completed, or at any time thereafter, the surplus cement can be easily wiped off by rubbing with a kerosene-soaked swab. The cement may be allowed to dry, then made active again any number of times.

(4) If it is desired to have the cement set quickly, gasoline should be used, as kerosene, or a mixture of kerosene and oil, causes the material to harden very slowly.

(5) If during assembly the cement is forced out along the joint, it may be considered tight. If no surplus is seen, however, kerosene should be sparingly brushed along the joint on both sides.

(6) At points where there are reinforcements, or other points likely to cause trouble, a dripping coat of cement (Neoprene, type 1–T) should be brushed into the joint before riveting. An excess of this material can be removed by rubbing with the fingers.

(7) After completion of the structure, Neoprene cement should be brushed around all fittings and other points where leaks are apt to occur.

(8) Minor repairs may be easily accomplished by using this material especially if the airplane operates some distance from its servicing base.

(9) The tape should not be submerged in gasoline or kerosene to activate the cement, as continued submergence in either fluid will eventually dissolve the coating.

b. The following procedure illustrates a typical application of the tape to a joint:

(1) Select the proper width and length of tape and lay it on some absorbent material such as celotex. Brush one side with the activator selected and press into place. This procedure will keep the exposed side dry and the workman's hands clean.

(2) When the skin is ready to be applied, moisten the tape in the area to be covered by that particular piece and clamp or screw in place. It is desirable to have the tape on the stringer at least 24 hours before riveting, although a shorter period is satisfactory, providing the material can be drilled and handled without undue slippage. While there is no time limit for closing the joint, if the rivets are not set soon after the skin is added, both edges and the exposed holes must be brushed with kerosene.

42. Metal floats.—When metal floats have been dented only slightly they may be hammered back into shape by using a wood block and mallet back of the dents. A long piece of soft wood may sometimes be used to work out spots where a mallet would not reach. Where the dents have caused sharp bends in the metal, it is advisable to reinforce by patching, even though no cracks may be seen. When deformities or slight dents are found just forward of the step on aluminum-alloy floats, they must be corrected or they may cause the airplane to nose over under certain conditions. Hammering must be reduced to a minimum to prevent damage to the extent that corrosion will set in. A patch should never be made over the dented or torn metal surface without first bringing the metal back into shape, and removing the paint so that the damaged section may be carefully examined for cracks. In the event a patch is required, the following procedure should be used (see fig. 83).

a. Carefully trim out holes, cracks, etc., with shears or a hacksaw, to a regular shape of sufficient size to reach sound metal.

b. Cut out a patch large enough to overlap the edges of the hole approximately 5⁄6-inch all the way around, using Alclad sheet 10 percent thicker than the damaged material.

c. Lay out a row of rivet holes approximately ¼-inch from the edge and four diameters of the rivet between centers. The diameter of the rivet depends on the thickness of the sheet.

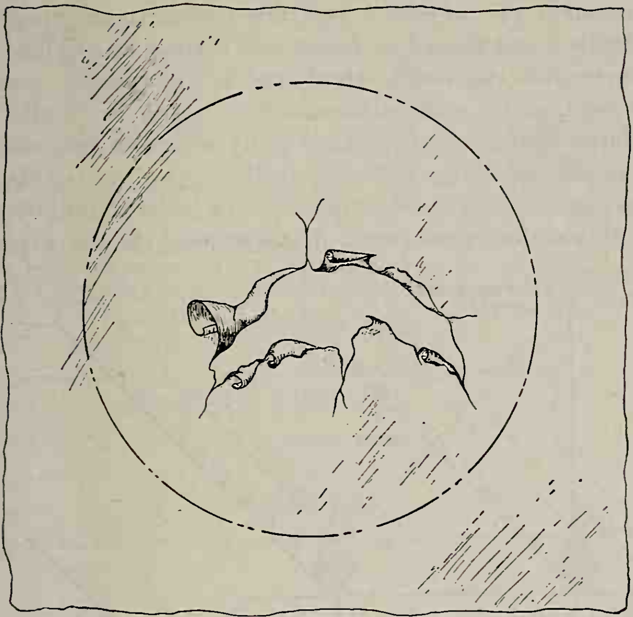
d. Drill 3 or 4 holes through the patch and the part being repaired, then fasten the patch in place with screws until the remainder of the holes can be drilled. Be sure the patch is held firmly in place before drilling holes.

e. To prevent leaks mercerized cotton fabric soaked in a special spar and seam compound varnish should be placed between the patch and the part being repaired. The patch should always be applied on the outside.

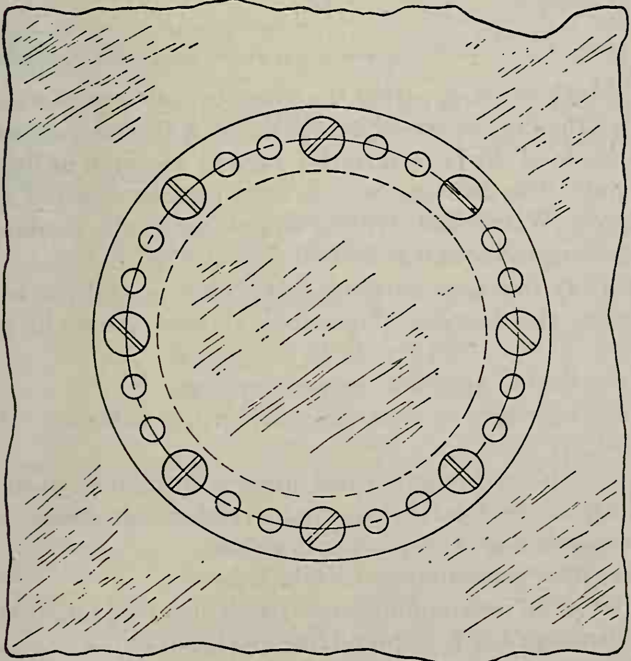
f. In an emergency, sheet-metal screws or steel-machine screws may be used until a permanent repair can be made. In this case, it is necessary that the exact size drill be used for sheet-metal screws and *a more complete repair made as soon as possible.*

g. When large areas are damaged, it is often advisable to remove a portion of the deck, and in some cases the removal of an entire sheet may be required. Special care should be taken to see that all seams are made watertight when replacing the parts. This may be facilitated by using an extra stiffening strip (fig. 84).

h. Where the flotation compartment is a part of the airplane, the repairs are made in the same manner as previously described for smooth or corrugated stressed skin. In addition to being strong



① Extent of damage.



② Application of patch.

FIGURE 83.—Repair of damaged section in seaplane float.

enough to carry the necessary load this compartment must be made watertight by using the cotton fabric and varnish as specified above.

43. Corrosion-resistant steel parts.—Corrosion-resistant or stainless steel parts, such as ammunition boxes, fire walls, etc., are usually fabricated by spot-welding or by a similar patented process known as shot-welding. Where facilities are available, repairs should be made using the same method. In order to remove damaged sections of stainless steel parts, it is necessary to use a small high speed grinding wheel, applying the wheel to each separate weld. The sheets may then be separated by the use of a thin, flat chisel, preferably one made of the same material, such as a section of flat stainless steel tie rod. The damaged section must then be replaced and again spot-welded. Where spot-welding equipment is not available, either of the following methods may be used (see fig. 85 ① and ②).

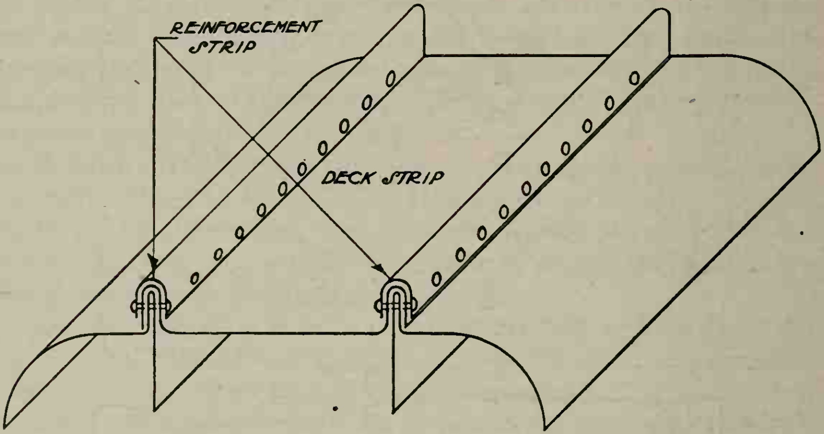


FIGURE 84.—Application of deck and stiffening strip on seaplane float.

a. Cut away damaged portions only, being careful not to mar the welded seam and leaving, if possible, at least 1 inch of metal for flange.

(1) Trim hole to square or rectangular shape.

(2) Turn up edges ½ inch, and make patch to fit hole with edges also turned up ½ inch.

(3) Rivet in place through turned up edges, using steel rivets.

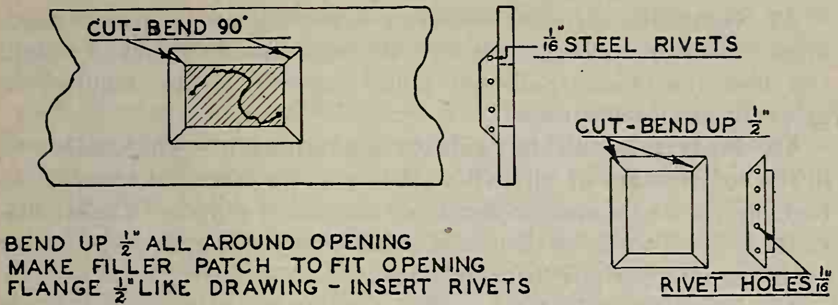
(4) Solder inside of part being repaired and smooth down.

b. Cut away damaged portions as in *a* above.

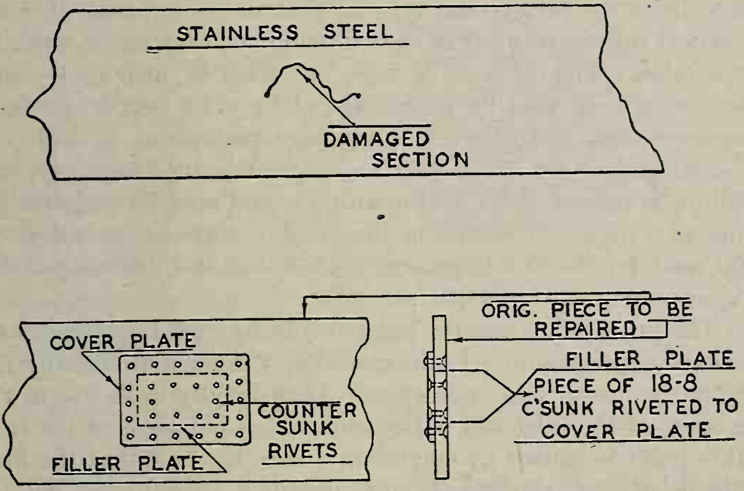
(1) Make filler patch the exact size of hole.

(2) Rivet to an overlapping cover patch, one inch larger than hole, using countersunk-head rivets and forming heads on outside.

(3) Rivet cover patch to part being repaired, and solder seams.


CUT-BEND 90°
1/16" STEEL RIVETS
CUT-BEND UP 1/2"
BEND UP 1/2" ALL AROUND OPENING
MAKE FILLER PATCH TO FIT OPENING
FLANGE 1/2" LIKE DRAWING - INSERT RIVETS
RIVET HOLES 1/16"

① Flange type patch.


STAINLESS STEEL
DAMAGED SECTION
COVER PLATE
COUNTER SUNK RIVETS
FILLER PLATE
ORIG. PIECE TO BE REPAIRED
FILLER PLATE
PIECE OF 18-8 C'SUNK RIVETED TO COVER PLATE

② Flush type patch using reinforcing plate.

FIGURE 85.—Repair of stainless steel parts.

SECTION IX

RADIATOR REPAIR

Paragraph
General 44
Materials used in radiator construction 45
Tubular radiator 46
Honeycomb radiator 47
Radiator cleaning 48
Testing radiators 49
Radiator tanks 50
Leaks around fittings 51
Prestone radiators 52
Oil temperature regulators 53

44. General.—Aircraft radiators are designed to give a maximum amount of cooling efficiency with a minimum amount of weight and heat resistance. Sufficient liquid capacity is also required to properly cool the medium.

45. Materials used in radiator construction.—The metals used in the construction of aircraft radiators are copper and brass. The tanks are, as a rule, made of brass and the core of copper. These materials are used because of their heat conductivity, strength, easy forming qualities, and resistance to corrosion.

46. Tubular radiator.—*a.* The tubular radiator is used in the Air Corps on trucks and tractors. The construction of this radiator differs from the honeycomb type in that it is composed of a series of vertical tubes, arranged in rows or columns, varying in depth from 4 to 8 tubes. The columns or rows are from ¾ inch to 1½ inches apart, being separated by thin strips of brass or copper, perforated to accommodate the tubes, and are arranged about ⅛ inch apart. These strips are known as fins and have the threefold purpose of holding the tubes rigid, forming an increased area for radiation, and acting as a means of retarding the air flow through the tubes. The metal used for the fins is generally 0.005 inch in thickness, while the tanks are constructed of 0.040 inch stock.

b. The principal causes for leaks in tubular radiators are vibration, freezing, and corrosion. Leaks caused by vibration are usually found to be in the header and tank seams. Occasionally leaks due to vibration occur at the inlet and outlet connections but most of the trouble at this point is caused by corrosion, due to the fact that the fittings are made of cast iron, which rusts readily. In radiators where the header leaks are so numerous that to repair them individually from the outside of the tank would be impractical, it is much easier to remove one of the tank panels and resolder the entire header from the inside.

c. In repairing leaks, the radiator must be properly cleaned before soldering is attempted. Leaks due to freezing present the most difficulty, as the tubes are usually bulged at the seams, making it necessary to first close them to their original shape before soldering is attempted. This is accomplished with special tools made for the purpose. After shaping, the tubes are cleaned by using a torch with a large flame and a good liquid flux. The heat and flux causes all paint and dirt to fall away from the tubes, thus exposing their tinned surface for soldering. Wire solder is laid along the tubes on top of the fins and is melted in by the torch flame. As the tubes are already tinned, the solder flows around them and seals all the leaks. In case the radiator is of seamless tube construction, the leaks must be repaired individually by spreading the fins and using a small pointed flame.

47. Honeycomb radiator.—*a.* The honeycomb radiator differs from the tubular type in construction and principle in that it is designed to withstand severe freezing without leaking, and to give a greater surface for radiation. Units of this type are constructed of ribbon copper and brass; the width of the ribbon determining the thickness of the core. These ribbons are run through a forming die which gives the shape to the cells. After the ribbons are formed they are assembled, layer upon layer, until the desired size core is built up. The water channels are then headed off and the core is ready for the soldering vat. There are many different patterns of honeycomb cores but they are all designed to meet the same requirements.

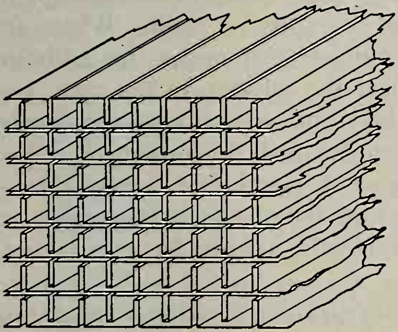


FIGURE 86.—Wing form, lateral type radiator core.

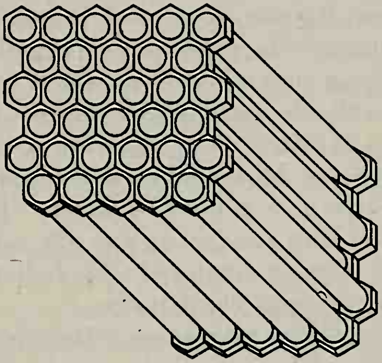


FIGURE 87.—Cartridge type radiator core.

b. The wing form, lateral type of radiator (fig. 86) is very difficult to repair and is not as strong as the cartridge type of core described in *c* below. The core is made up of small, seamless copper tubes approximately ¼ inch in diameter, with 0.006 inch wall thickness. These tubes are swaged to a hexagon shape on the ends for better fitting when soldering the faces. This type of radiator core is considered the most efficient cooler available, due to the fact that each tube is completely surrounded by liquid.

c. The cartridge core (fig. 87) is easily repaired and is the only type on which a temporary repair can be made when the necessary tools for a permanent repair are not available. As each passage is individual, this emergency repair can be made by plugging both ends of a damaged tube without affecting the efficiency of the radiator to any extent.

48. Radiator cleaning.—*a. Internal cleaning.*—Due to accumulating deposits of foreign matter in radiators, it is sometimes necessary to remove these obstructions in order to restore proper circulation. Mineral deposits are the usual cause of poor circulation, and can be removed by the use of a mixture of one part of commercial hydrochloric acid and three parts of water. This mixture is heated and poured into the radiator with all openings closed, except the one through which the filling is accomplished. The radiator is then allowed to stand for about 30 minutes, after which it is drained and flushed with clean water to neutralize the action of the acid. For deposits of oil and grease, a solution made of one pound of caustic soda dissolved in 7 gallons of water is used. When applying this solution, it is best to completely immerse the radiator. A suitable heating unit is used to heat the solution in the tank, and the radiator should be alowed to boil until clean. Should caustic soda not be available, a solution can be made by mixing 1 pound of lye in 5 gallons of water. The same method of application is used with the lye as with the caustic soda solution. Regardless of the cleaner employed, the radiator should always be rinsed thoroughly with clean water.

b. External cleaning.—Materials for cleaning a radiator externally consist of emery cloth, wire brushes, files, scrapers, and commercial hydrochloric acid. In case the radiator is covered with grease, the internal cleaning method is used for its removal. It is vitally important that parts to be soldered are made absolutely clean before any soldering is attempted.

49. Testing radiators.—In testing radiators all of the openings are closed with rubber plugs or cups, except the one through which the air is introduced. This is usually fitted with a filler cap having a short tube soldered to it to fit the air hose, and a pressure of 5 pounds is used on the initial test. The radiator is placed in a tank of water, and the air escaping through the leaks indicates their exact location and nature. Tank leaks may be marked with a scriber or pencil, and 2 or 3 marks should be made at the leak. By doing this, the leaks can be found readily after the radiator is removed from the testing tank. For leaks in the core, small wood plugs or a piece of wire solder bent to form a U can be inserted into the defective cell. More than 6 pounds of pressure should never be used for testing ordinary radiators and the exact location of every leak should be located. In emergencies, radiators may be tested by filling them with water and observing where the water leaks. This method is not used where air is available and should be confined to field repairs.

50. Radiator tanks.—*a.* Tank seam leaks caused by vibration, expansion due to a clogged vent tube, and crashes do not present difficulty in repair if the repairman is careful to remove the old solder and properly cleans the area around the leak. In the case of a crushed tank the tank must first be restored to its original shape before soldering. It is quite necessary that the seam is well fitted before soldering, as a small amount of solder is much more satisfactory than a large amount.

b. In repairing radiator tanks which have become cracked, the area around the crack should be cleaned thoroughly and a patch of brass or copper of a thickness equal to that of the tank material fitted to the crack. The patch should extend at least ½ inch beyond the crack on either end and about the same distance on both sides. This acts as a reinforcement for the tank as well as a repair to the leak caused by the crack. The shape of the patch depends entirely on the location of the break.

c. Radiator tanks that have been crushed can be repaired in several different ways. In the event that the tanks are badly crushed, it is best to remove either the top, front, or back plate and hammer the tank back to its original shape. After this is accomplished, and the tank properly prepared by cleaning, all seams may be fitted and soldered. Rivets that are cut to facilitate repair must be replaced by new rivets or their equivalent. A very good substitute for rivets is the Parker-Kalon self tapping sheet-metal screw. For minor dents in the tank, a curved piece of iron may be used to advantage by inserting it into the tank through the inlet or outlet connections and forcing the dent out. In the event a tool cannot be used in the tank opening, a bar of solder may be soldered to the dent at one end, worked back and forth, and at the same time pulled outward. Another method of removing inaccessible dents is accomplished by heating the dented area and quickly covering it with a rag soaked with cold water.

51. Leaks around fittings.—Leaks around fittings are usually due to vibration, although at times may be the result of corrosion. In resoldering these fittings, it is best to remove all of the original solder and clean and tin the parts. In the case of cast iron fittings, it may be necessary to remove them in order to clean the area under the fittings and to facilitate retinning. All rivets that have been cut to remove fittings must be replaced.

52. Prestone radiators.—*a.* Radiators for Prestone cooling systems are sometimes subject to operating temperatures near that of the melting point of soft solder. Therefore, Prestone radiators are soldered with high melting-point solder. This solder will develop a shearing strength of 1,500 per square inch at 350° F. and has a melting point of 580° F. to 700° F. The temperature for application should not exceed 850° F. when soldering hard-drawn copper and brass. This type of radiator may be identified by the data plates attached, which list the specification number of the solder used in their construction. Since the melting point of this solder is above that permitting the use of soldering coppers, application must be made by means of a radiator torch. To avoid damage to the tubes, only sufficient heat should be applied to properly flow the solder.

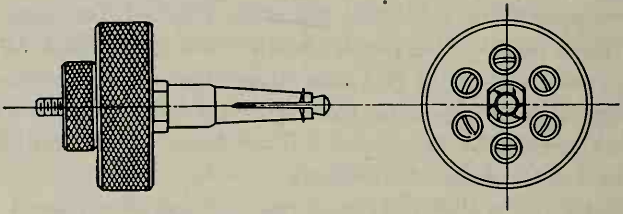


FIGURE 88.—Radiator tube cutter.

b. The repair of these radiators is a highly skilled operation, therefore, the following points should be carefully observed:

(1) The most important item in satisfactory repair is to have the surfaces clean. Before starting to repair any aircraft radiator, it will be first thoroughly cleaned inside and out and then steamed for 1½ hours. During this time the radiator should be located so that the steam passes downward and the condensate drains freely from the radiator.

(2) High melting-point solder solidifies very quickly after removal of the torch flame, and it is therefore necessary, when removing core tubes, to sever the tube and remove each end separately. For this purpose, a core tube cutter (fig. 88) has been designed that will sever the tube below the hexagonal section without damage to adjacent tubes. These cutters may be locally manufactured. The tool is operated by inserting the full length of the collet end into the radiator core tube and expanding the collet by turning the small knurled nut. With the collet thus expanded, the large nut is then turned to the right until the cutter rotates freely. After the end of

the tube has been cut in this manner, the solder should be melted with the radiator torch and while molten, the core tube end removed by means of a wire hook or other suitable tool. The remainder of the tube may be removed from the opposite side of the radiator core in the same manner.

(3) After tinning the ends and inserting the replacement tube, each end should be heated to remove the chill and surface moisture, then cleaned with zinc chloride flux which is the only flux that will give satisfactory results with high melting-point solder. Following the application of the flux, the tube may be soldered in place, using a radiator torch for flowing the solder.

(4) Radiators constructed with high melting-point solder must never be repaired with half and half, lead and tin solder.

c. Face seam leaks may develop from dirt being on the metal, preventing the flow of solder during the dipping of the core; while leaks caused by vibration are sometimes found near the edges of the core face. These leaks are repaired by opening the seams with a thin tool such as knife or old hacksaw blade which has been ground to a point for the purpose. After the seams have been opened, they are cleaned thoroughly, using a small wire brush or scraper. Occasionally, in a repair job, it is necessary to brush on a small amount of uncut acid to clean the metal. In such cases the uncut acid should be immediately and thoroughly washed with water before applying the zinc-chloride flux.

d. After repair, the radiators should be tested for leaks in warm water with compressed air at a pressure of not more than 10 pounds per square inch.

53. Oil temperature regulators.—*a.* On large engines, especially those operating in warm climates, the oil is cooled before it enters the oil tank by means of an oil temperature regulator or radiator. There are several types of oil coolers in use although their construction is practically the same. A typical unit is shown in figure 89. Before repairs are made on oil coolers they should be cleaned as prescribed for Prestone radiators. (See par. 52*b*(1).) Round type oil coolers should be located horizontally with the valve at the bottom and the steam connection attached at the 45° angle, that is, integral with the cooler.

b. Oil temperature regulators are fabricated with Grade A 50-50 lead-tin solder. The procedure for repair is similar to that for Prestone radiators. In soldering these units it has been found that the addition of a small amount of powdered sal ammoniac to the zinc-chloride flux helps clean the metal.

c. After repair the oil temperature regulators should be tested for leaks in warm water with an air pressure not to exceed 75 pounds per square inch.

d. Considerable difficulty has been experienced because of corrosion after repair. To avoid this condition, the following recommendations should be followed:

(1) After testing, the oil temperature regulator should be thoroughly washed inside and out with hot water. If no forced circulation is used, it should be immersed and drained several times.

(2) After washing, the oil temperature regulator should be steamed as previously prescribed, for a period of at least 1 hour.

(3) If the cooler is to be installed in an airplane and used immediately steaming may be omitted, but in this case it must be thoroughly dried, either by immersing in hot oil as outlined below or by baking in an oven at a temperature of from 250° F. to 275° F. for approximately 1 hour.

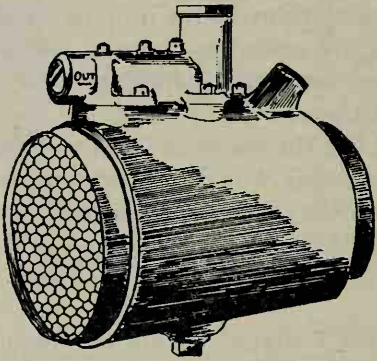


FIGURE 89.—Oil temperature regulator.

(4) If the oil temperature regulator is to be stored for a period longer than 20 days, a hot oil treatment should be given to remove moisture and give the internal surfaces a protective coating. The oil temperature regulator should be completely immersed in a tank of engine oil, preferably of a viscosity corresponding to SAE 20. During this operation the oil should be maintained at a temperature of 250° F. The oil temperature regulator or radiator should be agitated beneath the surface until all bubbling has ceased. Upon being removed, and while still hot, the oil should be drained as completely as possible and all openings closed in preparation for storage.

e. In handling, shipping, and storing oil temperature regulators, it should be realized that they are fragile assemblies of 0.006-inch wall copper tubes, soldered together. They must be handled carefully to avoid damage. The concentration of the entire weight on any one point, or a slight knock will, in many cases, result in injury.

SECTION X

FUEL AND OIL TANK REPAIR

	Paragraph
General	54
Construction	55
Testing and cleaning	56
Repairing	57

54. General.—The methods used in the construction and repair of fuel and oil tanks varies according to the size and material used in their construction. The majority of these tanks are made from aluminum and aluminum alloy although terneplate and brass sheet are used in some cases. The seams in all tinned steel or brass tanks are riveted with tinned soft iron or copper rivets and soldered, while seams in aluminum tanks are welded. Aluminum-alloy tanks are close riveted using a compound between the seams which is insoluble in gasoline. All fuel tanks contain baffle plates on the inside to prevent the fuel from surging and loosening the seams. Fuel tanks for general purposes are designed to withstand 3½ to 4½ pounds of internal pressure. The exterior surface is covered with two coats of air drying enamel.

55. Construction.—The procedure for the lay-out and assembly of fuel tanks, regardless of the kind of metal used, is very much the same up to the point where they are made fluid tight. The method of sealing depends entirely upon the character of the metal. The following description of construction principles refers directly to the use of half hard aluminum sheet; however, with modifications, they can be made to apply to the various other materials.

a. All fittings, ends, and rivet heads on aluminum fuel tanks should be welded. When welding, the area adjacent to the weld expands and forms a wrinkle. During cooling, a reverse action takes place but does not remove the wrinkle. This cannot be prevented; therefore, the tank must be beaded or swaged during fabrication to take care of expansion.

b. Large, flat surfaces in the shell of the tank should be avoided. The stiffness of aluminum is less than that of brass or steel so the thickness of the sheet should be greater. For example, a thickness of .051 inch is satisfactory for a 150 gallon tank. In the more common square or rectangular airplane tanks the corners should be rounded as much as practicable, and the flat sides stiffened with corrugations and baffles. These corrugations also assist in allowing for expansion and contraction, because of the heat of welding, and thus prevent buckling and warping of the shell of the tank.

c. Baffles should contain a large number of lightening holes and must be flanged for riveting to the shell. The tops of all rivets should be welded to prevent fuel leakage and the rivets used should be as small as possible; ⅛ inch in diameter being large enough for sheets up to .051 inch in thickness. Rivets should be headed over just enough to hold, otherwise welding difficulties may be encountered. Where possible, baffle plates and bulkheads should be made and riveted together before being installed in the shell of the tank.

d. Side seams on the tank shell are usually locked, grooved, and calk-welded. The fittings, such as filler necks, gage fittings, and sump fittings are made of aluminum tube or castings and welded to the tank. To prevent warping, a bead should be placed concentrically with the fitting. It is sometimes advisable to rivet castings to a piece of ¼-inch sheet aluminum, after which the assembly may be welded to the tank. The ends of the shell and tank ends should be beaded and flanged for flange welding and put in place last.

56. Testing and cleaning.—The procedure for testing tanks varies somewhat from that of testing radiators. All openings are closed except the one through which air is introduced, and with the tank under an air pressure of 2½ pounds, each seam, rivet, and fitting is tested with soapy water. Leaks will be indicated by the appearance of bubbles. To eliminate danger from possible ignition of explosive gases when repairing aircraft tanks that have contained fuel or oil, the following precautions should be taken:

a. No repairs requiring the application of heat will be accomplished on fuel or oil tanks while installed in aircraft.

b. A tank requiring repairs by welding or by the use of any open flame must, before such repairs are attempted, be drained and thoroughly cleaned.

(1) The tank must be flushed for 15 minutes with hot water admitted at the bottom of the tank and allowed to overflow at the top. This is to remove deposits of oil or fuel adhering to the sides of the tank.

(2) After flushing with water, the tank will be cleaned with live steam; the steam being passed through the tank for a minimum period of 3 hours for fuel tanks and 1 hour for oil tanks. The tank must be mounted so that an opening is available at the top and one at the lowest point of the tank. The live steam will be fed in at the

top opening and allowed to escape through the bottom, while all other openings are closed.

(3) If facilities for steam cleaning are not available, the flushing with hot water should be continued for a minimum period of one hour, following which the interior of the tank will be thoroughly dried with compressed air. This is not as positive a method of removing combustible material and fumes as steam cleaning; therefore, it should not be used unless absolutely necessary.

(4) When the exterior of the tank is to be cleaned with paint remover, or any other combustible solvent, this cleaning should be done prior to the flushing or steaming.

(5) The repair work must be accomplished as soon as possible after the tank has been cleaned and dried. Under no circumstances should a tank that has been flushed or steam cleaned and dried be allowed to stand more than 30 minutes before being repaired. Tanks that are allowed to stand in excess of this period must be recleaned before applying any heat.

c. When repair can be accomplished by soldering with a copper it will not be necessary to steam-clean the tank provided all fuel or oil has been completely drained from the tank and caution is used in heating the soldering coppers. The coppers should not be heated to a temperature where they will cause particles of dust to become incandescent, as this is sufficient to ignite any explosive mixture in the tank.

d. Welding of tanks that have contained fuel or oil should never be accomplished near any combustible materials or in any building containing such materials.

57. Repairing.—*a.* The repair of removable tanks consists principally of repairing seams, line connections, crushed sections, leaks around rivet heads, and cracks. The process of repairing depends entirely upon the material of which the tank is constructed. In case of aluminum tanks, repairs are made by the welding process with the exception of aluminum and aluminum-alloy tanks which are nickel plated. In this case, leaks can be repaired by soldering, provided the nickel has not been scratched off. Paint and oil should be removed from nickel plated tanks with paint remover and no cleaning attempted with a wire brush or scraper.

b. Many fuel and oil tanks are constructed of aluminum-alloy sheet and have riveted seams that are filled with a sealing compound. Due to this construction, and the fact that no heat is required for repairs, the tanks must not be cleaned with steam as this will loosen the sealing compound and cause leaks.

(1) When checking these tanks for leaks, the following procedure should be used:

(*a*) Lay the tank on its side in a shallow tray filled to a depth of approximately 3 inches with light machine oil.

(*b*) Apply air pressure, either through the sump connection or the filler opening, with all other openings closed. The pressure should never exceed 3½ pounds per square inch.

(*c*) Locate leaks by observing air bubbles in the oil as the tank is slowly turned.

(2) Minor seepage or vapor leaks can be treated with an external application of Thiokol G–18 compound. This compound may be obtained from the Thiokol Corporation, Yardville, N. J., and application should be made as follows:

(*a*) Clean all grease and dirt from the area to be treated and brighten the metal with steel wool.

(*b*) Using a small paint brush, such as a sash brush, apply a thin coat of Thiokol. Allow this to dry approximately 30 minutes then brush on a coat of Thiokol about 1/16 inch thick and allow to dry for approximately 48 hours before testing. Support the tank for the first few hours so that the freshly applied compound will not flow away from the treated area.

(3) Dripping or running leaks, due to a tank being open or split, cannot be treated effectively with Thiokol alone and repairs should be made as follows:

(*a*) Drill out all damaged or loose seam rivets in the vicinity of the leak.

(*b*) Tighten all remaining rivets along the seam for a distance of approximately 3 inches on both sides of the leak using a pneumatic squeeze riveter, if available, and working toward the faulty portion from both sides.

(*c*) Install new rivets where necessary, dipping them in Thiokol before driving.

(*d*) Apply Thiokol along the seam and around the rivets as described then test the tank for leaks after 48 hours, being careful not to allow the air pressure to exceed 3½ pounds per square inch. If a pressure test shows that the leaks have not been effectively stopped, it will be necessary to apply Thiokol to the seam internally. This may necessitate cutting a handhole to provide access to the end seams and certain portions of the longitudinal seams. Handholes should be cut, when possible, in the flat top surface of the tanks in a location that will not interfere with the structure of the airplane.

(4) Bulkhead leaks may be repaired as follows:

(*a*) Small seepage or vapor leaks around a bulkhead rivet can be treated with Thiokol as described.

(*b*) If the rivet is loose or located near the bottom of the tank where it is subjected to pressure due to the static head of fuel, it is advisable to replace it with a new rivet and apply Thiokol to the inside head. The procedure is as follows:

1. Remove the sump fittings and filler for access to rivets.
2. If rivets are not accessible through these openings, cut handholes as previously described.
3. Chip off the external rivet head of the faulty rivet and remove the seal washer.
4. Drive the remainder of the rivet into the tank and shake it out through the handhole or fitting opening.
5. Dip a new rivet in Thiokol and insert it from the inside. Replace the external seal washer with fresh Thiokol on the bottom.
6. Drive the rivet and apply Thiokol to the inside of the tank.
7. Test for leaks after 48 hours.

c. Fuel tanks built integrally with the airplane structure have riveted seams filled with a sealing compound and must be thoroughly dried before any repairs are attempted. Tanks constructed in this manner must not be steam-cleaned, as this will loosen the sealing compound nor may they be repaired by welding or any application of heat, as the drying specified below will not completely remove explosive fumes.

(1) To dry these tanks, first remove all handhole covers and pass a current of air, not to exceed 100° F. (38° C.), through the tank until thoroughly dry. This will take several hours, possibly over night, and is necessary to insure that the sealing compound will stick to the sides of the tank. This is also an added safety precaution, as the fumes in an empty fuel tank are highly explosive.

(2) Do not attempt to stop a leak at an accessible rivet by applying compound. The exact location of the leak can be determined by applying a pressure of approximately 2 pounds to the inside of the tank and testing with soap suds. If the leak is at an accessible rivet, drill out the old rivet and two or more rivets on either side. Do not attempt to remove rivet heads with a chisel, as this will elongate the holes. Soak a piece of cotton tape in spar and seam compound varnish and calk the area to be repaired. Coat the new rivets with the compound and drive tight.

(3) If a leak cannot be traced to an accessible rivet, determine the

general location of the leak. Without scraping, remove all loose pieces of varnish from the inside of the tank. (This does not apply to tanks that have not been previously repaired.) Using a spray gun with the nozzle bent so that the spray can be directed to the position desired, spray the leaking portion thoroughly, but no heavier than necessary, with varnish. This sealing compound can also be satisfactorily applied with a brush. Any excess varnish which has drained to the lowest parts of the tanks after a period of 30 to 40 minutes should be removed. Allow this coat to dry for 12 or more hours and repeat the procedure. If the leak is very bad, three coats may be necessary.

(4) After repairing a tank it is advisable to test it for leaks, using 2 or 3 pounds of air pressure and soap suds.

(5) It has been found that airplanes having integral fuel tanks will develop numerous leaks due to drying out of the calking compound if the airplane is allowed to stand for any considerable period of time with the tanks empty. Tanks that depend on sealing compounds to prevent leakage should therefore be refilled as soon as practicable after having been emptied.

(6) Whenever an airplane is being given a major overhaul, the entire fuel system, including the tanks, should be cleaned of all dirt, sediment, and other foreign substances.

SECTION XI

AIRPLANE PLUMBING

Paragraph
General………… 58
Aircraft piping identification………… 59
Copper and brass lines………… 60
Aluminum and aluminum-alloy lines………… 61
Corrosion-resistant metal lines………… 62
Attachment fittings………… 63

58. General.—The materials used for tubing in airplane plumbing are copper, brass, aluminum, aluminum alloy, and corrosion-resistant metals, such as 18–8 stainless steel and Inconel.

59. Aircraft piping identification.—All aircraft plumbing is marked with ½-inch bands of different colors of enamel.

TABLE XIX.—*Color identification for aircraft plumbing*

Color	System
Red.	Fuel.
Yellow.	Oil (lubricating).
White.	Coolant (water).
Brown.	Fire extinguisher.
Light blue.	Flotation equipment.
Light green.	Oxygen.
Black.	Airspeed—pitot pressure.
Light green—black.	Airspeed—static pressure.
White—black—white.	Coolant (Prestone).
White—light blue.	Manifold pressure.
White—light green.	Vacuum.
Light blue—light green.	Air pressure (compressed).
Light blue—black.	Steam.
Light blue—yellow.	Purging.
Light blue—brown.	Exhaust analyzer.
White—red.	Fluid (ice preventive).
Red—black.	Vent (closed compartments).
Light blue—yellow—light blue.	Hydraulic pressure oil.

60. Copper and brass lines.—*a.* Copper tubing is used to a great extent for aircraft plumbing. It is easily bent to almost any desired curve and, when properly annealed, it rarely cracks. Continued vibration causes lines made from copper and brass tubing to become brittle at points subjected to flexure. This brittleness increases with a continuation of the flexing and, if not annealed, the tubing will eventually break.

(1) To prevent such failures, each copper or brass fuel, oil, water, and pressure gage line is annealed prior to initial installation, and after each overhaul of the equipment on which it is installed. The annealing is accomplished by heating the tubing to a temperature of approximately 1,000° F. After heating, brass lines are allowed to cool at room temperature. Under no circumstances should they be quenched, as a sudden reduction in the temperature of heated brass will, as a rule, cause it to crack. Copper is cooled by quenching, which also removes or loosens the scale caused by heating. Copper lines should be quenched immediately after annealing, providing this can be accomplished without chilling any brass parts that may be attached.

(2) New copper and brass lines should be fabricated from tubing in the annealed condition only. Close bending work hardens the metal and each line should be annealed at all close bends after the forming has been accomplished, regardless of previous annealing.

(3) All scale and other foreign substances should be removed from the inside of each line before installation.

(4) Copper tubing has usually been annealed prior to purchase although, if the tubing seems hard, it should be annealed before bending.

b. The most important consideration in bending tubing is the shaping of the section without causing it to buckle or flatten.

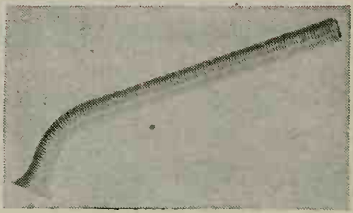


FIGURE 90.—Coil wire tube bender.

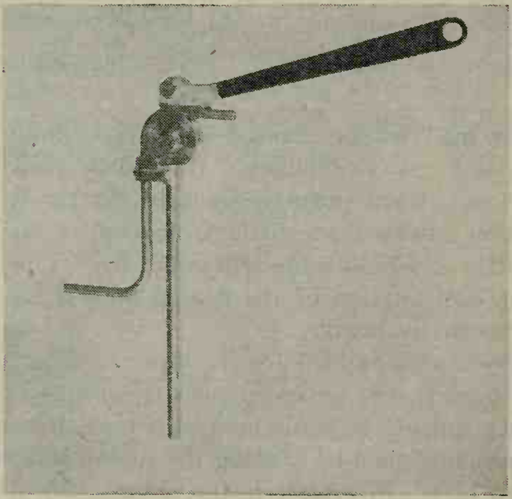


FIGURE 91.—Hand tube bender.

(1) Tubing up to ¼ inch, such as is used for airspeed lines, etc., may be bent in the hands without flattening or buckling if care is taken to work the curve gradually.

(2) Medium size tubes (from ¼ to ⅝ inch), such as are used for fuel lines, small oil lines, etc., may be bent successfully by using a coil wire tubing bender (fig. 90) of the correct size. The coil wire bender is slipped over the tube where the bend is to be made and the desired curve formed by hand. If a sharp bend is needed, it is better to form

the tubing around a hardwood block of the proper shape. After the bend is complete the bender may be removed by twisting and pulling at the same time. A hand bending tool (fig. 91) may be obtained for bending tubing from ⅛ to ¾ inch in diameter. Several sizes are available and their use does not require filling of the tube.

(3) Large size tubing (from ⅝ inch up) such as is used for oil lines, should be filled before bending to prevent buckling. A method which may be used on tubing up to ¾ inch is to stop one end of the tube with a tight fitting wooden plug, completely fill the tube with fine dry said, then plug the open end. The plugs must fit tightly in the tube or they will be forced out when the bend is made. Forming should be done over a wood forming block. Tubes 1 inch in diameter and over may be filled with melted rosin. The tube should be warmed with a torch to prevent the rosin from hardening when it strikes the cold metal. This precaution is important, as the tube will buckle if it is not filled completely with the rosin. The tube may either be bent cold or warmed slightly. After the correct bend is made, the rosin is melted out of the tube by heating with a torch.

61. Aluminum and aluminum-alloy lines.—*a.* Aluminum or aluminum-alloy lines do not require periodic annealing.

b. As an aid in bending, a fusible alloy may be used as a filler. This material consists of 26 to 28 percent lead, 12 to 14 percent tin, 48 to 50 percent bismuth, and 10 to 12 percent cadmium. The alloy can be used without damaging the physical properties of aluminum-alloy tubing as it melts at 68° F., flows freely at temperatures as low as 170° F., and may be bent readily when cold. The following points must be observed when using this fusible alloy as a filler for tube bending:

(1) One end of the tube must be closed sufficiently tight to prevent leakage.

(2) Only steel ladles should be used for this purpose and they must be kept clean and free from all traces of other metals.

(3) The tube to be filled and the ladle containing the fusible alloy is immersed in a tank of water, at or near the boiling point, until the alloy has melted. A hot-water tank similar to that used for plating is suitable for this purpose. For long sections, special tanks may be constructed of a length of pipe used so that both the tube and the ladle will be completely submerged.

(4) When the fusible alloy has melted it is poured into the tube to be bent, keeping both tube and ladle beneath the surface of the hot water during the pouring operation so that the molten metal displaces the water in the tube. When sufficient metal has been

poured to fill that portion involved in the bend, the tube should be removed from the hot water tank and placed in cold water in a position which will retain the metal in the desired part of the tube.

(5) As this alloy bends readily when cold but breaks when warm or under suddenly applied loads, it must be fully cooled when the bend is made and the tube bent slowly. Any suitable tube bending apparatus may be used for the forming operation.

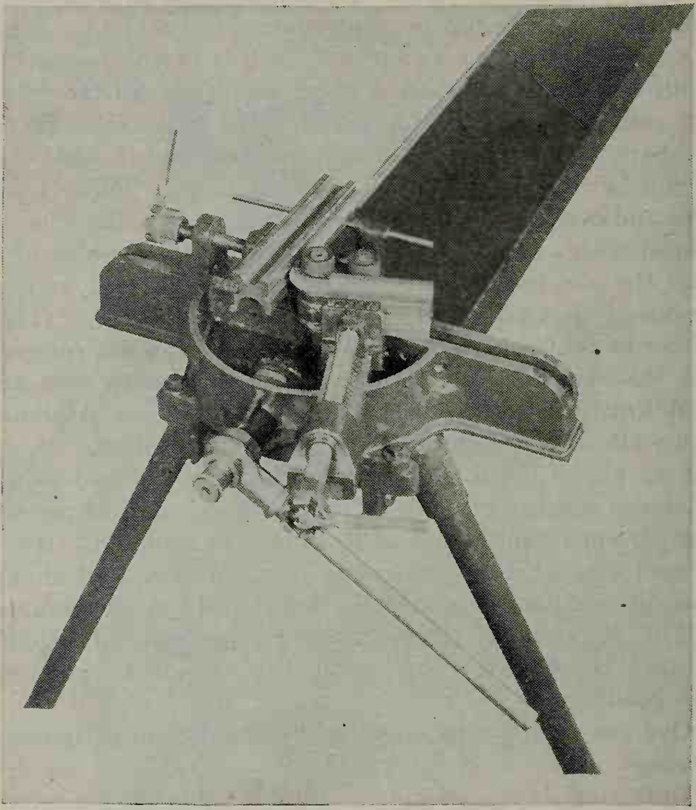


FIGURE 92.—Production tube bender.

(6) Upon completion of the bending, the tube and ladle should again be immersed in the tank of hot water and the alloy poured back into the ladle. Both tube and ladle must be kept beneath the surface of the water to reduce the tendency of the alloy to stick to the inside of the tube.

(7) The fusible alloy should be stored where it will not accumulate dust and dirt. It may be remelted as often as desired, and metal lost by spilling should be recovered.

(8) The alloy must never be melted in a furnace or over a flame, as the melting point is raised by overheating and the metal is rendered worthless. If the tubes are heated over a flame, in the air, to remove the alloy, particles of the metal may stick to the inside causing rapid local corrosion.

c. In depots and maintenance shops where considerable tubing is bent, a tube bending machine such as is shown in figure 92 is used. With this machine it is possible to bend true curves without filling the tube.

62. Corrosion-resistant metal lines.—*a.* A special machine is available for bending stainless steel and Inconel tubing. This machine is also adaptable for use with copper, brass, or aluminum-alloy lines, and is capable of making any bend up to 90° with an inside radius equal to the inside diameter of the particular tube to be bent. The machine and tools will bend 0.064 inch wall tubing 2 to 5 inches in diameter and up to 6 feet in length without heating. The bends are made without wrinkles and with very little distortion, by means of a mandrel and ball, the travel of which is synchronized with a semicircular, rotating table in which the tubing is clamped with geared clamp vises. In the bending of odd sizes of tubing for which tools are not available bends can be made by filling the tube with standard half and half solder and detaching the mandrel and ball mechanism from the machine. The steel tubing must be annealed before bending and perfectly dry to prevent the sudden explosion of the molten solder, due to the formation of steam. The tube is then closed at one end with a wood plug or a steel disk, welded on. The inside wall should be oiled lightly with machine oil to prevent the filler from sticking. Only half and half solder is recommended, as lead is too brittle and tin not sufficiently flexible to make a good bend.

b. Where there is no bending machine available, tubing up to 3 inches in diameter can be bent by hand using any of the following methods provided the tube is filled and any wrinkles, resulting from the bend, ironed out with a raising hammer before removing the filler:

(1) By using hard wood forms or blocks cut to the desired radius of bend and grooved to the tube diameter.

(2) By using a tube larger in diameter and approximately 12 inches in length. This tube section should be bellmouthed at one end and held in a vise. The bend is made by inserting the tube to be bent into the oversize tube and pulling it over the bell flange, forming the desired radius.

(3) By clamping the tube in a vise and pulling the bend in small increments, with a long piece of tubing used as a lever arm.

63. Attachment fittings.—There are three types of fittings generally used on aircraft tubing—the compression fitting, flared fitting, and soldered fitting.

a. The compression fitting is not used widely as this type of connection has a tendency to fracture the tube, causing it to fail under vibration.

b. A flared tube connection is shown in figure 93. This type of connection is very satisfactory if properly made. The most important consideration in flaring is to have the end cut off square and free from burs. This may be done by using a special hand-cutting tool (fig. 94). When a special cutting tool is not available the tube may be cut with a hacksaw, after which the ends must be filed smooth and true. With the tube cut and smoothed, the connection may be slipped on and the tube flared. It is important that a flaring tool be used which makes the correct flare without scratching or grooving the tube. The tube must be flared the correct amount so that the end of the tube is as wide as the cylindrical end of the tube-

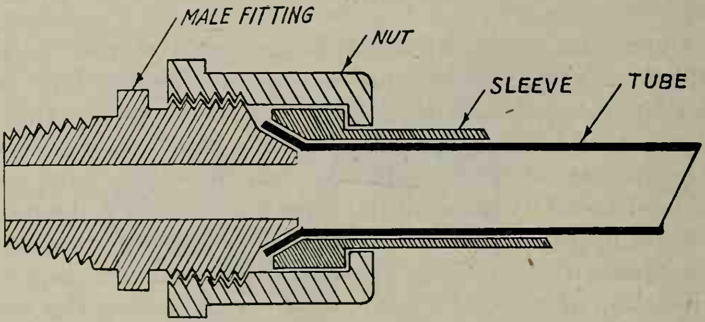


FIGURE 93.—Flared tube connection.

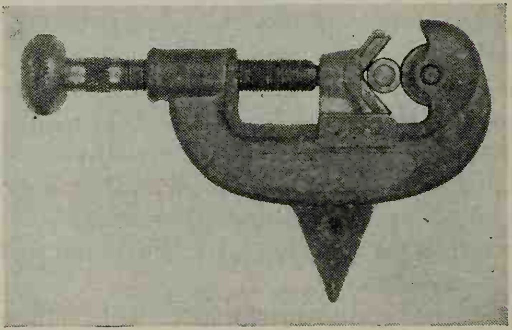
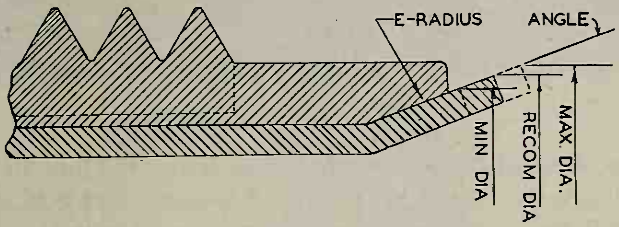


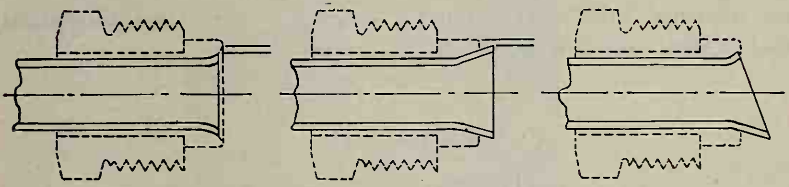
FIGURE 94.—Tube cutter.

coupling nut. Overflaring will reduce the wall thickness, particularly in aluminum tubing. Overflaring or underflaring will also cause trouble, as the flared metal will not match the tapered portion of the fitting. Figure 95 shows correct and incorrect tube end flares while figure 96 shows a typical type of flaring tool. When using this device, the tube must be tightly held in the correct size jaw and the flaring pin placed over the open end. The flare is made by striking the flaring pin several light blows. This tool may be used on aluminum and copper tubing from ¼ to ½ inch in diameter.

c. *Soldered fittings.*—Owing to the fact that soft solder will not hold under vibration and the annealing temperature of copper tubing is above its melting point, all copper and brass couplings, fittings, etc., must be attached by the use of a silver solder having a melting point above 1,000° F.



① Correct form.



② Incorrect form.

Figure 95.—Tube flare.

(1) The surfaces of the parts to be joined must be thoroughly cleaned in order to make a good union with silver solder. Grease and oil may be removed with any good alkaline cleaning solution or a small amount of gasoline, then rinsed in clean water. Scale or oxides can be removed by pickling and rinsing, or by emery cloth and steel wool.

(2) Flux must be used for silver soldering any metal. The flux prevents the oxidation of the metal as the temperature is raised to the soldering heat.

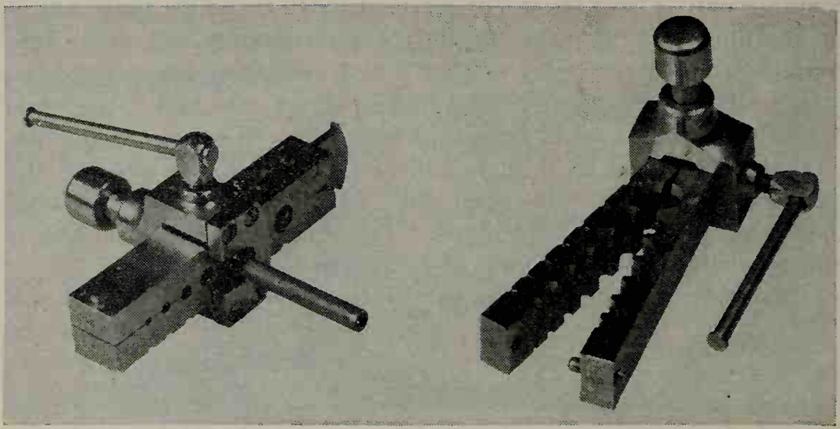


FIGURE 96.—Flaring tool.

(3) Care should be taken to avoid overheating the lines or fittings, as this will greatly weaken the metal. A gas and air torch, such as is used for radiator work, is satisfactory for silver soldering.

(4) Silver soldered parts should be immersed in a copper and brass pickling solution to remove flux and scale, then thoroughly rinsed in clear water before being put into service.

SECTION XII

PLASTIC SHEET FOR AIRCRAFT

Paragraph
General ---------- 64
Cutting ---------- 65
Bending ---------- 66
Installation ---------- 67
Cleaning ---------- 68

64. General.—Owing to its exceptional transparency, low water absorption, ease of cutting and forming, and its comparative freedom from vibration cracks, plastic sheet of an acrylic base is used in window lights, bomb bays, cockpit inclosures, and gun turrets in place of plate glass. This plastic sheet material is manufactured under several trade names such as, Lucite, Crystalite, and Plexiglas. Plastic sheets may be procured in thicknesses ranging from a few thousandths to ½ inch. A majority of the plastics are softened by heat and become hard again when they cool. Plastics that may be resoftened by heating are termed thermoplastics and this group includes the three types mentioned above.

65. Cutting.—Thermoplastics may be cut readily by the use of an ordinary band, circular, or jig saw. In cutting this sheet it is advisable to use a saw which does not have much set, and the material should not be cut with shears of any kind. Holes may be drilled satisfactorily by the use of an end mill, although ordinary metal drills may be used if care is taken to avoid grabbing, due to excessive pressure, when the drill penetrates the piece. During the cutting and other machining operations it is advisable to protect the plastic sheet by means of a suitable cover.

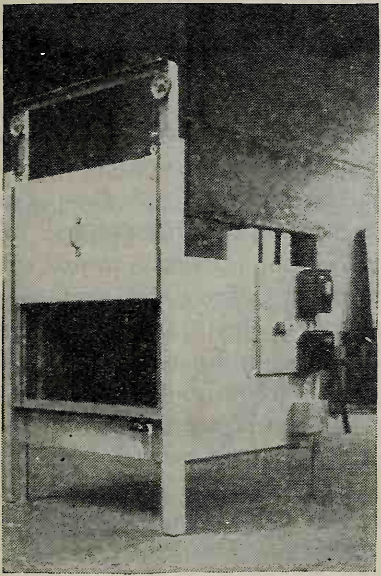


FIGURE 97.—Electric oven for heating plastic sheet.

66. Bending.—*a.* Thermoplastic plane sheets may be readily bent into two dimensional forms at elevated temperatures by observing the following recommendations:

(1) The surface of the material must be absolutely clean.

(2) The sheet must be heated from 190° F. to 250° F., depending on the thickness of the sheet.

b. An electrically heated hot air oven (fig. 97) in which dry, clean air is rapidly circulated, is most suitable for heating the plastic sheet. Hot oil, such as kerosene, may also be used as a heating medium. The sheet is most satisfactorily supported during the heating operation by hanging it in a vertical position, with clamps fastened along one edge.

c. The warm plastic sheet is bent over a cool wood or metal form covered with a soft cloth such as billiard felt. When a large number of pieces of complex curvature are to be bent from time to time, a plaster of paris form may be made up by using the original piece as a pattern.

(1) If the curvatures are of considerable depth the plaster form should be placed in a special airtight box with a rubber sheet fastened to the inside of the lid but allowed to remain loose in the center. When the lid is closed and fastened, air pressure is applied through a tube in the top of the lid, forcing the rubber sheet down into the mold.

(2) If time will not permit the making of a plaster mold, a box of sand may be used as a substitute. In such a case the original piece is used to make an impression in the sand and, after placing clean felt in this impression, the box of sand, with the plastic sheet in place, is set in the airtight box and air pressure applied. Care must be taken throughout the entire bending operation to prevent the heated plastic sheet from coming in contact with rough surfaces or dirt particles.

d. The warm plastic sheet should not be touched with bare fingers, as the material readily takes impressions. The sheet may be handled with clean cotton gloves without danger of damaging the surface.

e. When the sheet has been shaped, it should be allowed to cool on the form, after which it is removed, covered with masking paper, and trimmed to size.

67. Installation.—*a.* After forming, the sheet must be checked for size and shape. It is also necessary that the surface is free from any dirt. A piece of soft paper may then be fastened over both faces of the sheet with masking tape or paste, covering all but a ¾-inch margin to allow for installation. In pasting the paper on the plastic sheet, it must not be allowed to slide, as dirt or grit in the paste may cause scratches. This paper is for protection, and should remain on the sheets until installation and assembly have been completed. Its removal may then be accomplished with a wet sponge.

b. Plastic sheets are best installed in rubber, felt, or tape channels. Owing to the fact that the coefficient of expansion of plastic sheet is higher than that of metals, it is not advisable to fasten sheets in rigid frames by means of bolts, screws, or rivets, unless oversize holes are drilled in the sheet.

68. Cleaning.—*a.* In washing plastic sheet, care must be taken not to rub hard particles of dirt or grit into the surface. The surface should first be rinsed with water, then wiped lightly with a soft cloth. If the sheet becomes soiled with grease or oil, solvents for these substances, such as denatured alcohol, kerosene, naphtha, or carbon tetrachloride, may be used to remove the dirt. Solvents for plastic sheet, such as acetone, ethyl acetate, benzene, and ethylene dichloride, must not be used as a cleaner. These substances soften the surface of the plastic and, although through a general fluxing action cause the disappearance of many surface imperfections, this improvement is only temporary. The solvents also cause the material to swell and, on evaporation, leave the surface in a condition to readily absorb moisture and become cloudy.

b. The most effective material for the removal of fairly deep scratches is high grade automobile polish and cleaner. The cleaner is applied with a damp, soft cloth, and only the scratched area rubbed vigorously. The cleaner is then rubbed off with a clean cloth and the condition of the damaged area noted. Several applications of cleaner may be necessary, and when scratches are removed or considerably improved, the polish should be applied and removed in the same manner.

(1) Slight surface scratches may be removed by rubbing the sheet by hand with a soft cloth moistened with a turpentine-chalk mixture.

(2) Care should be taken not to press too hard or to cover a larger area than is necessary.

(3) Polishing cloths should be clean and free from grit. Before using, cloths should be washed with soap and clean water and allowed to dry in a room free from dust.

SECTION XIII

PROTECTIVE COATINGS FOR AIRCRAFT

Paragraph
General 69
Cleaning metal surfaces 70
Grease and oil coatings 71
Paint and enamel coatings 72
Metallic coatings 73

69. General.—*a.* Practically all aircraft metals, with the exception of the corrosion-resistant steels, are subject to corrosion when exposed to the atmosphere. For this reason various protective coatings are required to preserve them.

b. Protective coatings may be grouped into three classes, each being particularly adaptable for certain requirements.

(1) Grease and oil coatings.
(2) Paint and enamel coatings.
(3) Metallic coatings.

70. Cleaning metal surfaces.—*a.* Regardless of the protective coating to be used, all surfaces must be thoroughly cleaned prior to their application. This is necessary to insure proper adherence of the coating, and it is advisable to apply the protective material immediately after cleaning has been accomplished. The principal processes used for cleaning aircraft parts are as follows:

(1) *Sand blasting.*—Sand blasting or cleaning by mechanical abrasion is especially applicable where a considerable amount of scale is to be removed, and also where a rough or matted surface is desirable. All organic matter, such as grease or paint, should be removed before sand blasting.

(2) *Washing in organic solvents.*—Organic matter, such as grease and oil, may be removed by washing in benzol, carbon tetrachloride, naphtha, or other suitable organic solvents. Metals cleaned by this process must be thoroughly rinsed in clean, unused solvents before being coated.

(3) *Electro cleaning.*—Hot solutions of water and alkaline salts through which an electric current is conducted are considered very effective for removing organic matter from metals, preparatory to coating. A suitable tank is required which has facilities for conducting an electric current of approximately 6 to 12 volts through the solution as well as an arrangement for heating the solution to approximately 212° F. The cleaning solution consists of water and some approved plater's cleaner or metal cleaning compound. Udylite cleaner No. 7 or Okite plater's cleaner, mixed in proper proportions, have proven very effective for cleaning steel. If these cleaning compounds are not available, a solution of sodium carbonate (Na_2CO_3) and sodium hydroxide ($NaOH$) may be used successfully. Copper and copper alloys may be cleaned in the same solution in which steel is cleaned; however, this solution should not be used for aluminum, tin, or zinc, due to its chemical action on these metals. Where considerable aluminum cleaning is to be done, a separate tank containing a special solution for aluminum cleaning should be used. A solution of Udylite cleaner No. 11 is considered very satisfactory. After any metal is cleaned by means of an alkaline solution it should be thoroughly rinsed in clean water.

(4) *Pickling.*—Scale and oxides may be removed from metal by pickling in a solution of hydrochloric, sulfuric, or nitric acid. The choice of acid and the strength of the solution depend upon the

particular metal and the nature of the scale to be removed. After pickling, all articles must be thoroughly rinsed in cold water. *When mixing any acid solution, the acid must be added to the water to prevent dangerous overheating by chemical reaction.* The acid should be added slowly so as to allow time for the container to heat gradually.

b. Steel (except corrosion-resistant steel).—Steel parts may be cleaned as follows:

(1) Sand blasting.

(2) Washing in a solution of benzol, carbon tetrachloride, naphtha, or other suitable organic solvents.

(3) Immersion in a hot solution of alkaline salts through which an electric current of approximately 6 volts is conducted.

(4) Pickling in a 10 percent solution of hydrochloric or sulfuric acid at a temperature of 140° F. All organic matter should have been removed first by the electrocleaning process. This method applies particularly to heavily scaled parts.

c. Corrosion resistant steel.—Oxides and scale may be removed from corrosion resistant steel by immersing the part in an acid bath heated to 140° F. A suitable solution may be made by mixing 20 parts of nitric acid, 1 to 3 parts of hydrofluoric acid, and 77 to 79 parts of water. After the scale has been removed, the parts must be thoroughly rinsed in clean water and immersed in a 20 percent solution of nitric acid for 30 minutes. The treatment is then completed by a final rinsing in clean water.

d. Brass and bronze.—All organic material may be removed from brass or bronze parts in the manner as outlined for steel. Following this cleaning, the parts should be immersed in a "bright dip" heated to 95° F. and then rinsed in clean water.

(1) A suitable "bright dip" may be made by mixing 68 parts of sulfuric acid, 20 parts of nitric acid, 0.12 part of hydrochloric acid, and 40 parts of water.

(2) Parts which are heavily scaled, due to brazing, may be cleaned by dipping in a solution made by mixing one fluid ounce of sulfuric acid, 1.5 fluid ounces of sodium bichromate, and 1 gallon of water. This dip should be followed by a water rinse, immersion in the "bright dip," and a final water rinse.

(3) Soot or lamp black may be added to bright dips to form a "cover" over surface. The presence of this carbon counteracts any tendency to attack the metal in spots.

(4) If an excess of hydrochloric acid is in the dip, it causes brass to have a smoky or clouded color. This effect may be overcome

by mixing a small amount of soot with the solution and skimming it off after it has come to the surface.

e. Aluminum and aluminum alloys.—Aluminum and aluminum alloy may be cleaned by—

(1) Light sand blasting.

(2) Washing in organic solvents similar to those used for cleaning steel.

(3) Immersion is a hot solution of Udylite cleaner, No. 11, and water, in proportions of 6 ounces of cleaner to each gallon of water. (The use of caustic dips and acid pickles for cleaning is prohibited except in special instances.)

(4) Welding flux may be neutralized and removed by immersion in a 10 percent solution of sulfuric acid. It is important that the parts are thoroughly rinsed in water upon removel from the acid.

f. Magnesium alloys.—Grease and oil may be removed from magnesium alloys by washing in organic solvents or immersion in alkaline solutions as in the case of steel parts. Oxide and scale may be removed by light sand blasting or immersion for a few seconds in a 1 to 5 percent aqueous solution of sulfuric acid. The solution must be clean and free from metal salts. When a solution is used, the parts must be thoroughly rinsed after its application.

g. Soldered parts.—All soldered parts should be immersed either in a solution made by dissolving 2 ounces of sodium carbonate (soda ash) in a gallon of water, or an alkaline cleaner as specified for steel parts, to neutralize the soldering flux. A hot water rinse is necessary after removal from the cleaning solution.

71. Grease and oil coatings.—*a.* Grease and oils are used as a temporary preventive of corrosion for all steel parts which are to be stored or out of service for some time. Hot oil may be used as a permanent coating for some parts which are not accessible after assembly.

b. Threads on adjustable parts which are disconnected or disassembled should be greased before assembly.

c. The interior surfaces of all closed steel parts or members, and of plated parts which contain crevices or pockets, where the plating solution might be held, should be protected by a coating of raw linseed oil or an approved rust preventive compound. The liquid may be applied by forcing it into the hollow members under pressure or by immersing the part in a bath of the oil. In either case the liquid should be at a temperature of not less than 160° F during application and should be allowed to remain on the surface for at least 2 minutes. In large structure, interconnecting holes may be drilled between various members so that the liquid will circulate. The presence of the liquid in each member may be checked by noting the increase in temperature. Parts which are immersed should be manipulated so as to insure the prevention of air pockets. The members must be thoroughly drained after treatment and wiped free from oil on all exterior surfaces. Accessible holes, drilled in the members, should be closed with cadmium-plated Parker-Kalon self-tapping drive screws or their equivalent.

72. **Paint and enamel coatings.**—Many surfaces, both exterior and interior, may be satisfactorily protected by a coating of paint or enamel, provided they are properly cleaned, primed, and surfaced, prior to application.

a. Interior surfaces.—All interior surfaces should be primed or coated with aluminum-bituminous paint. Priming prepares the surface for subsequent finish coats, while bituminous paint may take the place of both primer and finish. When the latter material is used at least two coats must be applied.

(1) The finish for the internal parts of wings, control surfaces, and fuselages, may be any of the following:

(*a*) One thin coat of metal primer followed by one or more coats of the same primer containing aluminum powder.

(*b*) One coat of metal primer followed by one or more coats of aluminum-enamel or lacquer.

(*c*) Two or more coats of bituminous paint.

(2) Any of the above systems may be applied to engine mounts and similar assemblies.

(3) Passenger compartments and cockpits should be finished with one coat of primer followed by one or more coats of lacquer or enamel of the color required.

(4) Interior surfaces of floats, pontons, and hulls, which do not form luggage compartments, etc., should be given one coat of a mixture containing equal parts (by weight) of beeswax and petrolatum. This coating is in addition to the standard finish previously applied.

(5) Cargo, bomb, and luggage compartments should be finished with one coat of standard primer followed by one or more coats of tinted zinc chromate primer of the required color.

(6) Alclad parts, to be used for interior surfaces, should be coated with clear varnish to protect the material from scratches during fabrication. Upon assembly, this material may be considered as the primer and the top coats applied directly to it.

(7) Open end tubes and hollow parts may be filled with primer then drained, prior to being placed in service.

b. Exterior surfaces.—(1) *Training and amphibian airplanes.*—All exposed surfaces, regardless of material, should be finished in accordance with one of the following systems unless otherwise specified:

(*a*) Application of one thin coat of metal primer followed by two or more coats of oil enamel of the required color.

(*b*) Application of one thin coat of metal primer followed by two or more coats of cellulose nitrate lacquer of the required color.

(2) *Tactical airplanes.*—Unless specifically required, no paint except insignia and antiglare coatings should be applied to the exterior surfaces of parts such as wings, fuselages, control surfaces, and cowlings, which are fabricated from aluminum and its alloys or corrosion-resistant steel.

c. Miscellaneous requirements.—(1) *Surfaces over which doped fabric will be applied.*—These surfaces should be protected from the action of the dope by either of the following methods:

(*a*) One or more coats of dope-proof paint.

(*b*) Aluminum foil 0.0005 inch thick applied with water-resistant foil adhesive or shellac.

(2) *Antiglare coating.*—One coat of metal primer followed by one or more coats of flat bronze green lacquer or enamel should be applied to eliminate glare on such surfaces as the fuselage deck, forward of the pilot's compartment, and the inboard side of engine nacelles.

(3) *Cables, tie rods, etc.*—Corrosion-resistant steel cables or tie rods should not be painted, although their surfaces may be given a light coat of grease or oil. The ordinary carbon-steel cable should be coated with an approved rust-preventive compound or a mixture of tallow and white lead. Tie rod threads should be coated with an antifriction compound.

(4) *Supports for gasoline and oil tanks.*—Brackets and straps for this purpose should be lined with felt or fabric impregnated with spar and seam compound, or other water-resistant materials.

(5) *Joints and seams.*—The overlapping portions of all metal joints and seams should be given two coats of finishing material. The second coat may be either an additional coat of metal primer or a coat of aluminum varnish or lacquer. Bituminous paint may be used for both coats on joints and seams of parts and surfaces where the finishing scheme consists of aluminized-bituminous paint. With any of the above finishes the second coat may be either wet or dry when the assembly is completed. Several exceptions must be

made to the above procedure for finishing joints and seams. These exceptions are as follows and require no coating:

(*a*) All parts joined by welding, brazing, or soldering.

(*b*) Aluminum and aluminum-alloy parts which are anodized after assembly.

(*c*) Steel and brass parts which are cadmium plated after assembly.

(*d*) Contact parts of attachment fittings which act as connections between various units of the airplane, such as attachment points of the wings to the fuselage, engine control brackets, etc.

(*e*) Terminals for the various electrical systems.

(6) *Wearing surfaces, oil holes, etc.*—Care should be exercised to prevent the application of paint materials to wearing surfaces, threads, and oil holes.

(7) *Dissimilar metals.*—Dissimilar metal contacts, especially those between aluminum alloys and the alloys of copper and nickel, must be avoided wherever practicable. Copper alloys and steel parts in contact with aluminum alloys should be cadmium plated and then insulated.

(8) *Metal and wood contact.*—All wood parts in contact with metal should be insulated with marine glue, bituminous paint, or varnish. Bituminous paint should not be used where surfaces may come in contact with spilled fuel. Screws and bolts should be dipped in bituminous paint or spar and seam compound and inserted while the coating is wet.

(9) *Faying surfaces.*—The faying surfaces of hulls, floats, pontons, and flotation gears, should be assembled with flannel or airplane cloth, impregnated with bituminous paint, seam varnish, or other approved waterproofing materials, between the parts.

(10) *Hydraulic systems.*—No protective coating is required on the internal parts of hydraulic mechanism operating in mineral oil which are at all times immersed in the oil. Such parts, when not installed and immersed in oil, should be coated with a rust-preventive compound and wrapped in heavy paper.

73. Metallic coatings.—*a.* A large percentage of the metal parts used in airplane construction are given a metallic protective coating. The methods used are as follows:

(1) *Electroplating.*—This process may be used to apply many metals. Cadmium plate is, however, the one most generally employed for aircraft work and is fully treated in a following section which also describes electroplating in general.

(2) *Metal spray coating.*—This process consists of passing metal wire of the desired type through a specially constructed spray gun

which melts and atomizes the metal to be used as a coating. The surfaces to be sprayed must be roughened for satisfactory adhesion of the deposited metal, and sand blasting is usually employed for this purpose.

(3) *Hot dipping.*—Several metals may be satisfactorily applied by this means. The process consists of dipping the part to be coated in a vat containing the molten metal.

b. Electrogalvanizing (zinc plating).—Zinc is used to a certain extent for plating steel aircraft parts such as fittings, bolts, etc. Although zinc plating offers an excellent protective coating to steel, it is dull in appearance and the protective value is much less than an equal coating of cadmium. The minimum thickness of zinc plate for aircraft parts is 0.001 inch or 0.6 ounces per square foot. The dull appearance of zinc plating may be improved by the application of air drying, baked enamel, or lacquer.

c. Lohmannizing.—In this process the metal is first immersed in a bath containing an amalgamating salt, then pickled, and dipped in two or more different baths of molten alloys. The metals used in the baths are usually alloys of zinc, tin, and lead. Terneplate is an example of this process.

d. Parkerizing.—In the process of Parkerizing, the parts to be treated are immersed in a solution of phosforic acid and manganese dioxide heated to the boiling point. The parts are allowed to remain in the solution until gassing ceases then removed and dipped in oil. This finish is similar to gun metal.

e. Tinning.—A coating of tin, applied by dipping, is often used on parts where considerable soldering is to be done.

f. Anodizing.—This treatment is an electrolytic process applied to many aluminum-alloy parts. In general, the method consists of oxidizing the aluminum parts at the positive terminal of an electric circuit in an aqueous solution containing not less than 5 percent chromic acid by weight and not more than 0.5 percent sulfate. An electric current, variably controlled, is passed through this solution and after treatment, the parts are thoroughly washed in warm water.

g. Cadmium plating.—Cadmium is a white ductile metal having physical properties similar to tin and chemical properties similar to zinc. Ordinarily it should never be used as a coating where abrasion is encountered. Cadmium plating has practically taken the place of zinc plating in aircraft construction as it has very desirable protective properties as well as satisfactory appearance. According to tests, a cadmium coating is equal in protective value to a coating of zinc which is three times as thick. The minimum thickness of a cadmium coating for aircraft parts is 0.0005 inch (0.355 ounce per square foot).

h. Nickel plating.—Nickel plating may be applied to parts where a bright metallic luster is desirable. Although not used to a great extent for airplane materials, some few applications are made. Nickel is high in protective value if the coating is of sufficient thickness to be impervious. However, in order to secure maximum protective values, the nickel coating is usually preceded by a thin coating of copper (approximately 0.0003 inch). The final combined coating should not be less than 0.001 inch thick. Where corrosion is not a factor, as when coating brass, the nickel plate is usually 0.0001 to 0.0002 inch thick.

i. Chromium plating.—The outstanding characteristics of chromium plate is its comparative hardness and resistance to corrosion. It is used principally for articles such as precision tools, instruments, etc. In view of its comparative high cost, thin coatings of chromium are often applied over coatings of copper and nickel; this being especially true where tarnish is the principal factor. The thickness of the chromium plate in such cases is about 0.00003 inch. Where corrosion is the principal factor, the chromium plate should be 0.0002 inch or more in thickness.

j. Copper plating.—Copper plate is seldom used as a finish but is often used as an undercoat for nickel and chromium.

SECTION XIV

CADMIUM PLATING

Paragraph
General ---------- 74
Equipment ---------- 75
Plating process ---------- 76
Testing solutions ---------- 77

74. General.—Cadmium is deposited on the metal to be plated by means of an electrolytic process known as electroplating. In this process, the material to be plated forms the negative terminal or cathode of a direct current, electrical circuit, which is made complete through a plating bath known as an electrolyte. The bath is an aqueous solution of the metal forming the plate, which in this case would be cadmium in the form of a cadmium salt. As the electrical current passes through the electrolyte, pure cadmium is deposited on the cathode, or part to be plated, and during the process, the solution is weakened in proportion to the material deposited.

To offset this condition, a ball of the pure metal is suspended at the positive terminal or anode, where it dissolves and maintains the strength of the electrolyte.

75. Equipment.—The equipment required for cadmium plating consists of a direct current generator with suitable controls, a set of cleaning tanks, and an electroplating tank.

a. Electrical equipment.—The source of current supply is generally a direct current, motor generator set; although a storage battery may be used for small installations. The capacity of the generator required depends entirely upon the amount of plating to be done at one time. An estimate of the required generator output may be made by multiplying the number of square feet of surface to be plated by 20, which is usually considered the average ampere capacity required to satisfactorily plate one square foot of metal. A 6- to 12-volt generator capable of supplying 250 to 500 amperes is the size generally used for aircraft work.

(1) The output of the generator is regulated by means of a control assembly which consists of a main switch, voltmeter, ammeter, and rheostat, installed on suitable panel.

(2) The plating and cleaning tanks are provided with suitable anode and cathode rods, wiring, and a panel containing a rheostat, ammeter, and voltmeter placed within easy reach of the tank. The anodes are of brass rod or tubing and are usually located on the top of the tank, parallel to the sides. These rods should be of sufficient strength to withstand the weight of the plating metal and must be located in such a way as to prevent the anode containers from touching the sides of the tank. The positive lead from the generator is connected to these rods. If the lining of the cleaning tank is of steel it may be used as the anode and the positive lead from the generator connected directly to it, thereby eliminating the necessity for anode rods. The cathode is also a brass or copper rod or tube and is usualy located parallel to the anode rods on the top and center of the tank. It should be of sufficient strength to withstand the weight of the parts to be plated. The negative generator lead is connected to the cathode rod. When plating and cleaning tanks are of metal, both the anode and cathode rods must be insulated from the tanks.

b. Electroplating tank.—This unit may be either a glass, wood, or steel tank with provisions for the electrical connections previously mentioned. The size of the plating tank is determined by the maximum size of the articles to be plated. It should permit the parts to be completely immersed in the plating solution when suspended from the cathode rod, in a location that will allow approximately 2 inches of clearance between the parts and the tank. Generally, 10 gallons of solution will be required for plating an article having 1 square foot of surface area. In manufacturing plants where a large number of small parts are plated on a production basis, special devices in which the plating solution may be agitated or where the articles may be rolled and tumbled about are used extensively. A typical plating tank is shown in figure 98.

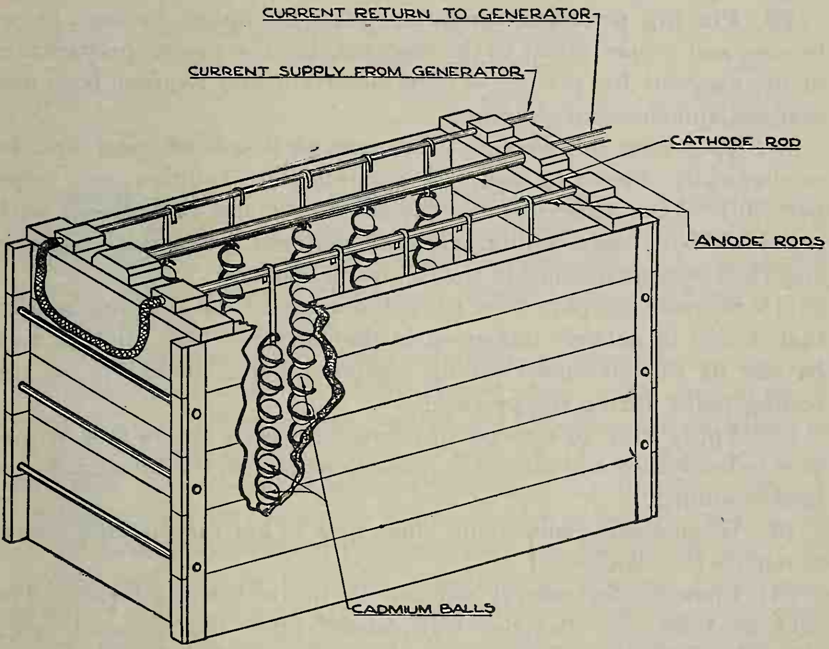


FIGURE 98.—Cadmium plating tank.

c. Cleaning and dip tanks.—In addition to the plating tank, vats are necessary for cleaning, rinsing, and dipping.

(1) The primary cleaning tank is usually constructed of wood with a steel lining. Its size depends upon the size and nature of the articles to be cleaned and it must have provisions for heating the cleaning solutions to approximately 212° F. For metal-lined wood tanks, electric immersion heaters or steam coils are usually used as a heating medium, while gas plates may be employed for steel tanks.

(2) The hot and cold water rinse tanks are very similar in construction to the cleaning tank, except that surface drains are provided so as to facilitate the removal of dirt and scum from the surface

of the water. The hot water tank may be heated by means of steam coils, electric immersion heaters, or a gas plate.

(3) Pickling tanks are usually constructed of wood with a lead lining. However, stoneware and glass crocks are also used.

(4) Bright dip solutions are usually contained in round or rectangular stoneware crocks. These crocks are placed in a tank of running water which serves to keep the solution cool, and also as a rinse for articles after they have been immersed in the pickling or bright dip baths.

76. Plating process.—Cadmium plate is applied to steel, brass, bronze, and copper direct to the base metal. The proper preparation of the material for plating is very important and requires both mechanical and chemical cleaning.

a. Preparation for plating.—The part to be plated must first be mechanically cleaned by means of a wire brush, sandblast, etc. (See par. 70.) After this cleaning, the surface should be polished with emery cloth or some similar abrasive material. Chemical cleaning may then be accomplished in the following manner:

(1) Suspend the part from the cathode bar of the cleaning tank so that it will be entirely immersed in the cleaner. This solution may be any of the alkaline cleaning compounds and should be at the boiling point during the process.

(2) Apply 10 to 20 amperes of current for each square foot of surface to be cleaned and allow the parts to remain in the solution for at least 5 minutes.

(3) When clean, remove and rinse, first in hot then in cold water, to remove the alkali.

(4) Immerse for several minutes in the pickling solution. The acid used for this purpose will depend upon the material being cleaned. For steel parts, a 10 percent solution of hydrochloric acid is satisfactory, while sulfuric or nitric acid is used for brass, bronze, and copper.

(5) Thoroughly rinse in hot water to remove all trace of the acid which completes the cleaning process.

b. Plating.—The deposition of the metal coating is made by suspending the parts in the electrolyte and regulating the current flow according to the surface area and thickness of plate required.

(1) Solutions used for cadmium plating are prepared by dissolving either cadmium oxide or cadmium cyanide in sodium cyanide. Other compounds are usually added to render the bath more stable and to produce a brighter plate.

(*a*) Any of the following solutions are considered suitable, although the third mixture is generally used by the Air Corps:

		Ounces per gallon of solution
1.	Cadmium oxide (CdO)	4.2
	Sodium cyanide ($NaCN$)	10
2.	Cadmium cyanide ($Cd(CN)_2$)	5.5
	Sodium cyanide ($NaCN$)	6.5
	Sodium hydroxide ($NaOH$).	2.7
3.	Cadmium oxide (CdO)	3
	Sodium cyanide ($NaCN$)	12.5
		Pounds per 100 gallons of solution
	Udybrite salts (commer)	4

Caution.—The sodium cyanide in the plating tank and the lethal gas which would be generated by introducing hydrochloric acid, are deadly poison. Any antidote is of doubtful value, unless used instantly, and therefore extreme care should be used to keep it away from the mouth, cuts, lungs, etc.

(*b*) The concentration of the solution may vary, depending upon operating conditions. For ordinary still plating, the solution should contain 6 to 8 ounces of free cyanide and 2.5 ounces of cadmium, per gallon. Sodium cyanide should be added to the solution at various intervals. The metal content of the solution is maintained, after the original mixing, by the anodes which are pure cadmium. New anodes should be added occasionally so as to maintain the correct metal consistency and may be procured in ball form, 2 inches in diameter, weighing approximately 1.25 pounds. They are placed in wire containers which are suspended from the anode rods in the plating tank.

(2) The parts to be plated are suspended from the cathode rod so as to be completely immersed in the electrolyte. Plating solutions are usually used at ordinary room temperatures, however, heated solutions may be used in some instances. An elevation in temperature tends to produce coarse deposits, although a finer grain may be caused by moving the cathodes or agitating the plating solution while using somewhat higher current densities. For still plating, using solutions at ordinary room temperature, a current density of 10 to 30 amperes per square foot of cathode surface is considered very effective. In warm agitated solutions a higher rate may be used. The time required for plating depends upon the operating condition. Using a normal plating solution, at ordinary room temperature, without agitation, the time indi-

cated in the following table is usually required to obtain a coating of 0.0005 inch thickness.

Amperes per square foot cathode surface	Time in minutes
10	40
15	25
20	20
25	10

After enough metal has been deposited the current should be cut off and the parts left in the plating solution for a short time to help "fix" the cadmium.

(3) Specific procedures for various classes of work are outlined as follows:

(*a*) Steel parts which have been welded.

1. Clean thoroughly in alkaline cleaning solution in electrocleaning tank.
2. Rinse in water.
3. Sand blast or pickle.
4. Rinse in water.
5. Immerse for a few seconds in cleaning tank.
6. Rinse in water.
7. Plate.
8. Rinse in cold and then hot water.
9. Dry thoroughly.

(*b*) Steel parts which are oily, dirty, and rusty.

1. Clean thoroughly in alkaline cleaning solution in electrocleaning tank.
2. Rinse in water.
3. Sand blast or pickle.
4. Rinse in water.
5. Immerse for a few seconds in cleaning tank.
6. Rinse in water.
7. Plate.
8. Rinse in cold and then hot water.
9. Dry thoroughly.

(*c*) Brass parts.

1. Clean thoroughly in alkaline cleaning solution in electrocleaning tank.

2. Rinse in water.
3. If tarnished, place in "bright dip".
4. Rinse in water.
5. Plate.
6. Rinse in cold and then hot water.
7. Dry thoroughly.

(*d*) Springs, or other articles subject to flexure, containing more than 0.40 percent carbon and with a final diameter or thickness less than ¼ inch, should be baked for 3 hours at from 350° F. to 400° F., after plating. Plated springs, etc., should not be flexed before the baking operation.

(*e*) Cadmium plated articles which are to be painted should, after the final water rinse, be immersed for 1 to 2 minutes in a 3 to 5 percent solution of chromic acid and then rinsed thoroughly in clear water. The tank used for rinsing articles from the cleaning and plating tanks must not be used after this operation. The chromic acid dip removes slight traces of alkali remaining on the metal surfaces after plating and also passivates the cadmium.

77. Testing solutions.—*a.* The thickness of plate may be tested by any of the following methods:

(1) Immersion of a sample specimen in a hydrochloric acid solution. In this test the length of time required to strip the specimen of cadmium will be an indication of the plate thickness.

(*a*) The stripping solution consists of a mixture of 73 cc. of hydrochloric acid, 27 cc. of water, and 2 grams of antimony trioxide. The temperature of this solution must be maintained between 60° F. and 75° F. and a fresh mixture used for each test.

(*b*) The specimen should be prepared by washing in alcohol and drying with a clean cloth. It is then immersed in the solution where it will gas freely. The exact time of gassing is noted in seconds, and the thickness of the plate read direct from the following table:

Gas evolution (seconds)	Plate thickness (inches)
20	0. 0001
30	. 00015
40	. 0002
60	. 0003
80	. 0004
100	. 0005

(2) *Udylite test.*—This analysis requires the use of a test set consisting of a number of liquids as well as the necessary dishes for making the tests. Complete directions for the use of this material are furnished by the manufacturers.

(3) *Weight analysis test.*—The thickness of the plate may be ascertained by determining the weight of the plate in ounces per square foot. This is done by weighing a specimen on which the plated area is known, before and after removal of the plate. The plate may be removed by means of the stripping solution given above, or a solution consisting of one pound of ammonium nitrate per gallon of water. The ammonium nitrate solution is used at ordinary room temperature and approximately 3 minutes will be required to remove the plate. Cadmium plate 0.0001 inch in thickness weighs 0.071 ounce per square foot.

b. Testing plating solution.—(1) When the plating solution consists of cadmium oxide and sodium cyanide, the concentration of free cyanide, sodium hydroxide, and metal may be calculated by means of the following factors:

(*a*) Each ounce per gallon of cadmium oxides requires 1.53 ounces per gallon of sodium cyanide to form the complex sodium-cadmium-cyanide. Sodium cyanide in excess of this amount remains as free cyanide in the bath.

(*b*) Each ounce per gallon of cadmium oxide used produces 0.62 ounce per gallon of sodium hydroxide (caustic soda) in the bath.

(*c*) Each ounce per gallon of cadmium oxide used produces 0.85 ounce per gallon of metal in the bath.

(2) The concerns from which the salts and anodes are purchased have prepared solutions for conducting tests of the plating electrolyte and the Udylite test is generally used by the Air Corps. When prepared solutions are not available, the following mixtures may be used with very accurate results.

(*a*) Cyanide test solution.

Cadmium chloride (anhydrous).	10 grams.
Water.	1 liter.

(Cadmium chloride containing 2 molecules of water requires 14 grams of salt per liter.)

(*b*) Metal test solution.

Flowers of sulfur.	145 grams.
Sodium hydroxide.	95 grams.
Water.	1 liter.

(Dissolve the sodium hydroxide in 500 cc. of water. Add the sulfur and allow to stand with occasional stirring until all of the sulfur is in solution. Add sufficient water to make 1 liter of solution.)

(3) Regardless of the solution used, the following procedures should be used in testing for free cyanide or metal content.

(*a*) To conduct a test of the plating solution for free cyanide, fill a small vial (1 to 2 drams) with the plating solution and pour it into a 6- or 8-ounce bottle half filled with water. Fill the same vial with cyanide test solution, pour it into the bottle containing the water and plating solution, and shake thoroughly. Continue adding the test solution, one vial at a time, and shake after each addition until the mixture becomes permanently milky in appearance (a slight milkiness will appear after each addition of test solution but will disappear on shaking). The concentration of the test solution is such that the number of vials required to produce a permanent milkiness represents the number of ounces per gallon of free cyanide in the plating solution. A normal plating solution should contain 6 to 8 ounces of free cyanide per gallon.

(*b*) To conduct a test of the plating solution for metal content, use a glass flask on which the capacity in cc. is marked. Pour 10 cc. of plating solution into this flask and then add 20 cc. of metal test solution. Cork the flask and shake until the two liquids are thoroughly mixed, then set it aside for at least 12 hours, during which time a yellow precipitate will settle to the bottom. As a standard basis for calculation, 3.5 cc. of precipitate represents approximately 2.5 ounces of metal per gallon in the electrolyte. The metal content in a normal plating solution should be 2.5 ounces per gallon. Excessive precipitate denotes excessive anode surface while insufficient precipitate indicates insufficient anode surface.

INDEX

	Paragraphs	Pages
Aircraft:		
Cable	27	74
Terminals:		
Tuck spliced	29	78
Wrapped	28	77
Parts, corrosion resistant steel, repair of	43	102
Protective coatings	69–73	127
Tie rods	30	80
Aluminum:		
Lines, plumbing of	61	119
Sheet metal	15	46
Aluminum alloy:		
Lines, plumbing of	61	119
Sheet metal	16	47
Bending	37	86
Brass line plumbing	57	113
Bumping:		
Hand	34	82
Metals formed by	36	84
Methods	33	82
Power	35	83
Cable, aircraft	27	74
Terminals:		
Tuck spliced	29	78
Wrapped	28	77
Cadmium plating:		
Equipment	75	136
Process	76	138
Testing solution	77	141
Coatings, protective, for aircraft:		
Cleaning metal surfaces for	70	128
Grease and oil	71	130
Metallic	73	133
Paint and enamel	72	131
Copper:		
Lines, plumbing of	57	113
Sheet, and its alloys	19	57
Coppers, soldering, use	7	37
Covers, skin, stressed, repair of	40	90
Dzus fasteners	26	74
Equipment, cadmium plating	75	136
Fittings, attachment, plumbing of	63	122
Floats, metal, repair of	42	99
Fluxes, soldering	8	37
Forming methods	33	82
Iron sheet	18	57
Joints and seams	10	38
Lead sheet	20	58
Leaks around radiator fittings	51	107

	Paragraphs	Pages
Lines, plumbing:		
Aluminum and aluminum alloy	61	119
Copper and brass	60	117
Corrosion-resistant metal	62	121
Machines	1	1
Nuts, self-locking	25	72
Paint and enamel coatings for aircraft	72	131
Plastic sheet	64–88	124
Bending	66	125
Cleaning	68	126
Cutting	65	125
Installation	67	126
Plating, cadmium	74–77	135
Plumbing, aircraft:		
Aluminum and aluminum alloy lines	61	119
Copper and brass lines	60	117
Corrosion-resistant metal lines	62	121
Fittings, attachment	63	222
Piping identification	59	116
Pressing, power	35	83
Radiators, aircraft:		
Cleaning	48	106
Construction, materials used in	45	104
Repair:		
Honeycomb type	47	105
Leaks around fittings	51	107
Oil-temperature regulator	53	109
Prestone type	52	108
Tanks	50	107
Tubular type	46	104
Testing	49	106
Regulators, oil-temperature	53	109
Repairs, aircraft:		
Radiators	44–53	104
Sheet work	38–43	86
Corrosion-resistant steel parts	43	102
Floats, metal	42	99
Open-section members	39	87
Skin covers, stressed	40	80
Skin seams, waterproof	41	98
Riveting	11, 22	41, 59
Rivets	22	59
Sheet metal:		
Bumping and forming methods	33–37	82
Dzus fasteners	26	74
Holders, spring	24	72
Nuts, selflocking	25	73
Properties and uses:		
Aluminum	15	46
Aluminum alloys	16	47

	Paragraphs	Pages
Sheet metal—Continued.		
Properties and uses—Continued.		
Copper and copper alloys	19	57
Iron	18	57
Lead	20	58
Steel	18	57
Corrosion resistant	17	53
Rivets	22	59
Screws, types and uses	23	69
Work:		
Development, methods	13	43
Elements of	9–13	38
Forming, principles	12	42
Joints and seams	10, 41	38, 98
Repairs	38–43	86
Riveting	11, 22	41, 59
Skin:		
Covers, stressed, repair	40	90
Seams, waterproof, repair	41	98
Soldering:		
Coppers, use	7	37
Fluxes	8	37
Hard	6	36
Soft	5	35
Tanks:		
Fuel and oil:		
Cleaning	56	112
Construction	55	111
Repairing	57	113
Testing	56	112
Radiator, repair	50	107
Tie rods	30	80
Tin work, riveting in	11	41
Tools:		
Bench	2	1
Hand	1, 3, 34	1, 24, 82
Bumping	34	82
Floor	2	1
Turnbuckles	32	81
Wire, steel, high strength	31	81

[A. G. 062.11 (11–4–40).][2]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
E. S. ADAMS,
Major General,
The Adjutant General.

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TECHNICAL MANUAL

AIRCRAFT SHEET METAL WORK

CHANGES No. 1 }

WAR DEPARTMENT,
WASHINGTON, December 31, 1941.

TM 1–435, February 10, 1941, is changed as follows:

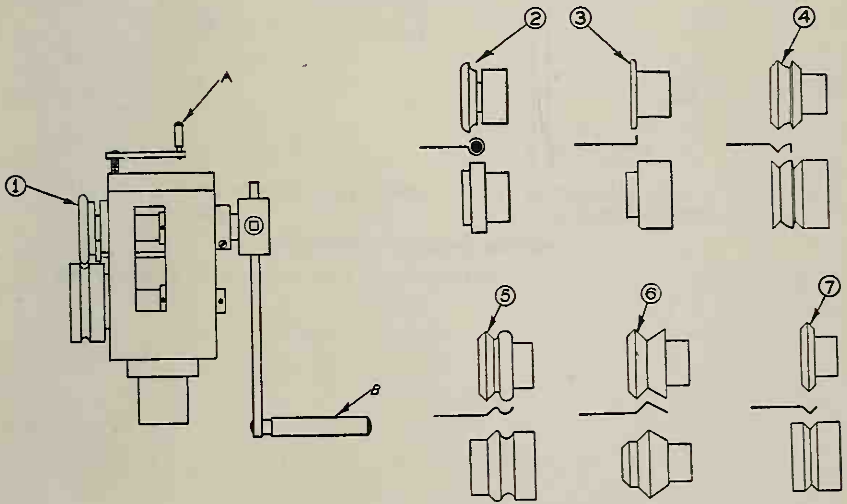
2. Floor and bench tools.—*a.* The machines and tools described herein are all used in connection with aircraft sheet metal work; however, many of them are also used in other phases of the sheet metal industry.

* * * * * * *

(17) *Elbow machine.*—The elbow machine is the same in construction as the turning machine, with the exception of edging rolls, which vary in shape according to the type of edge desired. These rolls will fit any standard make of turning machine and are illustrated in ④, ⑤, ⑥, and ⑦, figure 13.

* * * * * * *

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)



1. Turning rolls.
2. Wiring rolls.
3. Burring rolls.
4. Elbow edging rolls.
5. Elbow edging rolls.
6. Elbow edging rolls.
7. Elbow edging rolls.

FIGURE 13.—Machine and rolls for turning, wiring, burring, and elbow edging.

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

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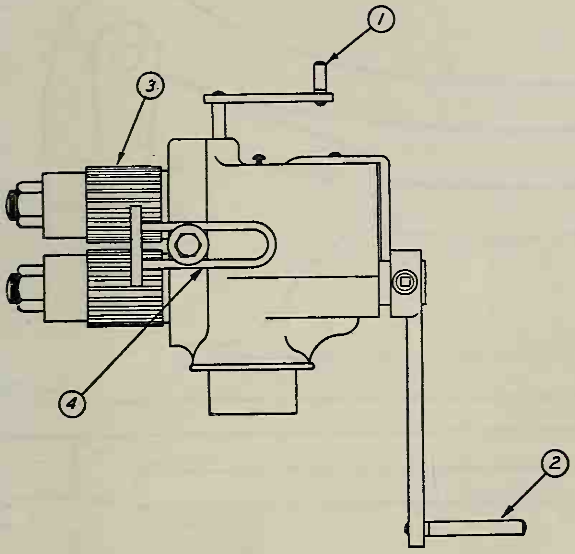
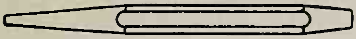


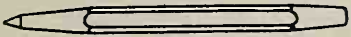
1. Vertical adjustment handle.
2. Crank.
3. Crimping rolls.
4. Adjustable gage.

FIGURE 16.—Crimping machine.

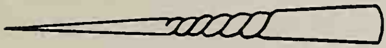
[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)



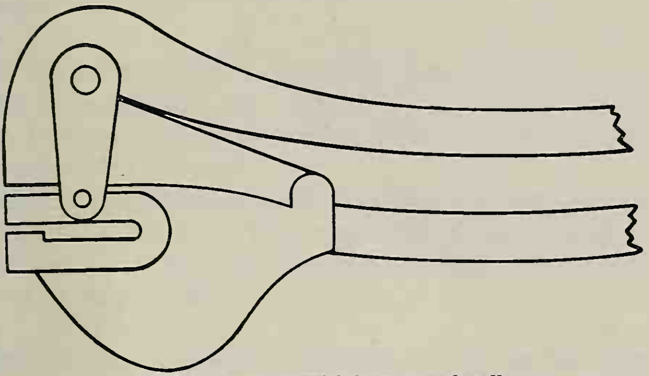
① Solid punch.



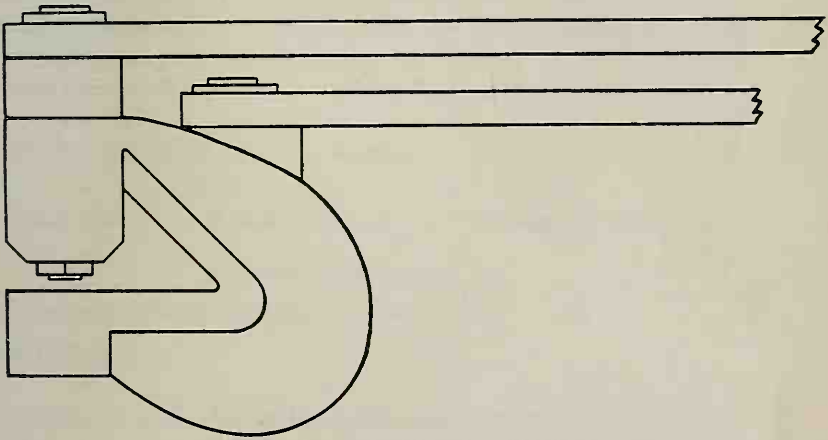
② Center punch.



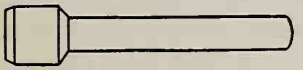
③ Prick punch or scratch awl.



④ Whitney punch with lever type handle.



⑤ Whitney punch with rotary type handle.



⑥ Hollow punch.

FIGURE 26.—Sheet metal punches.

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

6. Hard soldering.—Hard soldering is a process of soldering with a composition of copper, zinc, silver, and tin. This solder is used * * * invariably fracture with repeated vibration.

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

10. Joints and seams.—* * *

* * * * * * *

c. The single lock (fig. 39③) is formed on the cornice brake or bar folder and is made by turning the edges in opposite directions for the opposing sides to be joined. The sides * * * the work is to be watertight.

* * * * * * *

e. The double seam (fig. 39①) is commonly used in fastening the bottoms on cans, buckets, tanks, etc. This seam may be made either on the folder or burring machine as a single edge and then pounded over a suitable stake with a mallet.

f. The concealed lock is sometimes used on corners and tops of boxes where a flush finish is desired. This seam (fig. 39⑤) is soldered lightly on the outside. A box thus seamed is usually made to fit closely in a recess of other material.

* * * * * * *

h. The Pittsburgh lock somewhat resembles a large double seam. It is used on large rectangular elbows and pipes or where it would be impractical or impossible to use a stake for double seaming. This joint is formed on the cornice brake before any other forming is done on the metal. * * * to make a flush surface on the outside.

* * * * * * *

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

* * * * * * *

① **Double seam.** ② Double lock seam. ③ **Single lock seam.**

* * * * * * *

FIGURE 39.—Locked seams.

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

15. Aluminum.

* * * * * * *

c. Aluminum sheet is obtainable in two standard grades of temper—half hard and dead soft (fully annealed). Half hard aluminum is used wherever possible while dead soft sheet is generally selected for severe forming operations. Annealing is accomplished by heating the metal to a temperature between 625° and 700° F.

* * * * * * *

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

61. Aluminum and aluminum-alloy lines.

* * * * * * *

b. As an aid in bending, a fusible alloy may be used as a filler. This material consists of 26 to 28 percent lead, 12 to 14 percent tin, 48 to 50 percent bismuth, and 10 to 12 percent cadmium. The alloy can be used without damaging the physical properties of aluminum-alloy tubing as it flows freely at temperatures as low as 170° F. and may be bent readily when cold. The following points must be observed when using this fusible alloy as a filler for tube bending:

* * * * * * *

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

65. Cutting.—Thermoplastics may be cut readily by the use of an ordinary band, circular, or jig saw. In cutting this sheet it is advisabe to use a saw which does not have much set and **with approximately 16 teeth per inch.** The material should not be cut with shears of any kind. Holes may be drilled satisfactorily by the use of an end mill. **An** ordinary metal drill, **ground to an included angle of 60°**, may be used if care is taken to avoid grabbing **which results when excessive pressure is applied to the drill.** During the cutting and other machining operations it is advisable to protect the plastic sheet by means of a suitable cover.

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

66. Bending.—*a*. Thermoplastic plane sheets may be readily bent into two dimensional forms at elevated temperatures by observing the following recommendations:

* * * * * * *

(2) The sheet must be heated **to a temperature between** 190° **and** 250° **F. and allowed to soak from 3 to 6 minutes. The temperature and soaking time depend upon** the thickness of the sheet.

* * * * * * *

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

67. Installation.

* * * * * * *

b. Plastic sheets are best installed in channels **lined with** rubber, felt, or **cotton** tape. **The use of these materials tends to minimize leaks and the effects of vibration.** Owing to the fact that the coefficient of expansion of plastic sheet is higher than that of metals, it is not advisable to fasten sheets in rigid frames by means of bolts, screws, or rivets, unless oversize holes are drilled in the sheet.

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

68. Cleaning.—*a.* In washing plastic sheet, * * * may be used to remove the dirt. **If alcohol is used it should be wiped off thoroughly and quickly.** Solvents for plastic sheet, such as acetone, ethyl acetate, benzine, and ethylene dichloride, must not be used as a cleaner. These substances * * * and become cloudy.

* * * * * * *

[A. G. 062.11 (10–8–41).] (C 1, Dec. 31, 1941.)

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